Computer Image Processing

Lecture 8

Digital filters

- gradient
- nonlinear

Shift and subtract filters

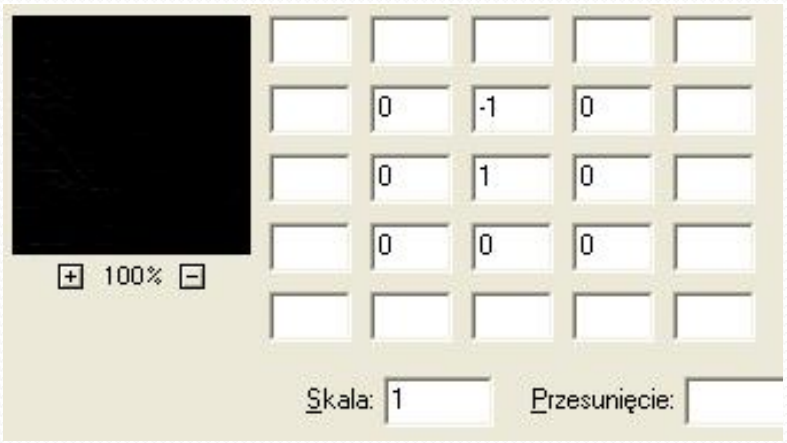
Shift and subtract filters make a copy of the image and then shift it by 1 pixel and subtract the image from its copy.

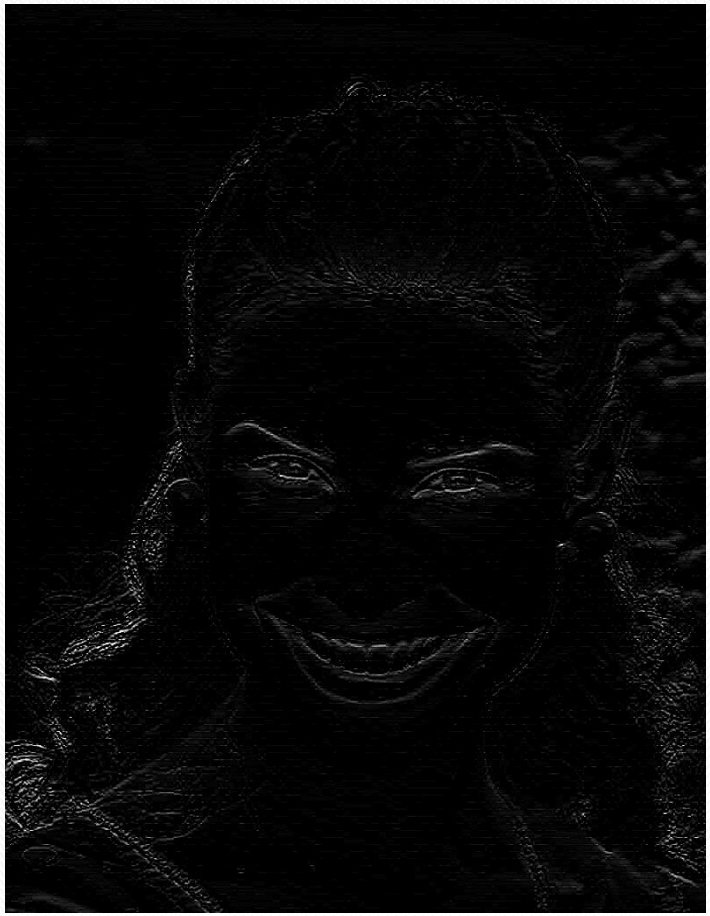
In areas where rapid changes in brightness occur, a high pixel values appear as a result of the operation, in regions with rather average values the resulting pixel values are low.

These filters are therefore used to detect vertical and horizontal edges in images.

Shift and subtract filters

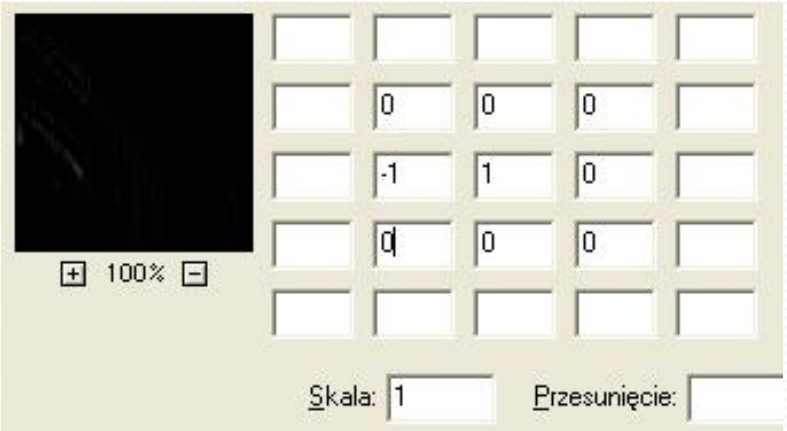
Horizontal filter and its effect.





Shift and subtract filters

Vertical filter and its effect.



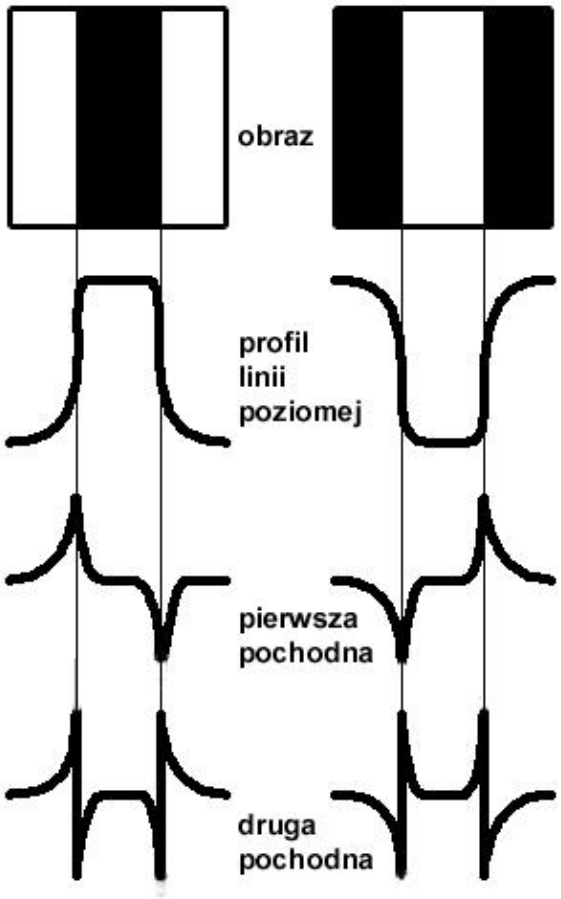
Edge detection filters

Detection of edges as borders between areas with different levels of brightness.

The general rule is to compare local derivatives of the brightness function.

The first derivative allows to state the existence of the brightness limit, the second - whether the transition takes place towards the lower or higher values.

Because the edge determines a sharp change in the brightness function, then gradient methods with a defined threshold are used to detect it.



Edge detection filters

Roberts operators

The simplest gradient operators, using the 2 x 2 kernels.

1	-1		1	0		1	0		0	1
0	0		-1	0		0	-1		-1	0

Disadvantages:

- high noise sensitivity,
- low edge sensitivity,
- ambiguity of the anchor point (even number of pixels)

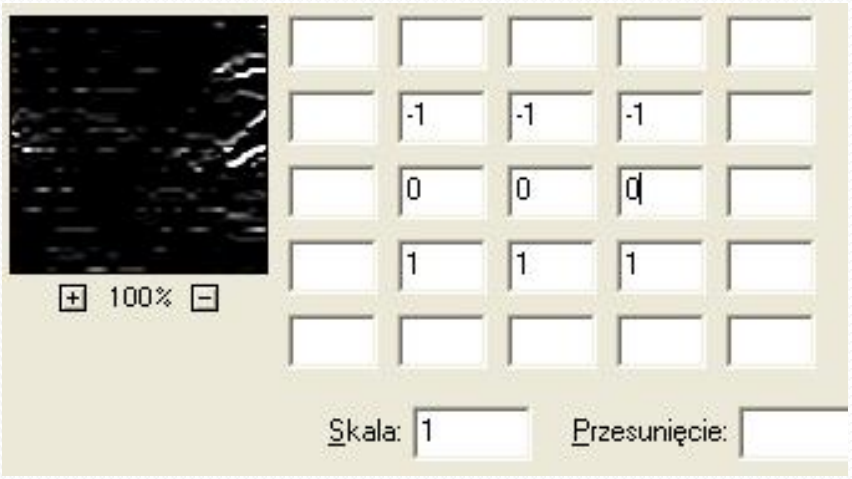
Edge detection filters

Prewitt operators

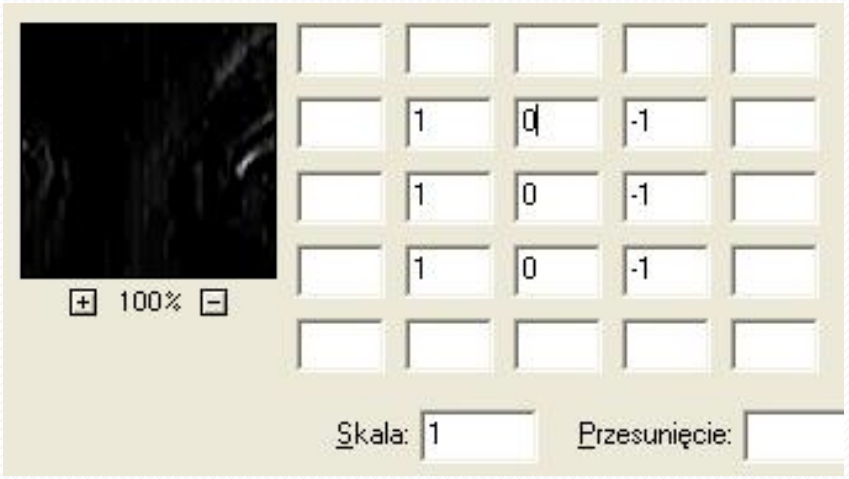
Filters that use first derivative for analysis. Kernels were created as an extension of Roberts operators to the 3 x 3 window size. Coefficients have values -1, 0 ,1.

Gradient could be analyzed in 8 different directions.

Edge detection filters

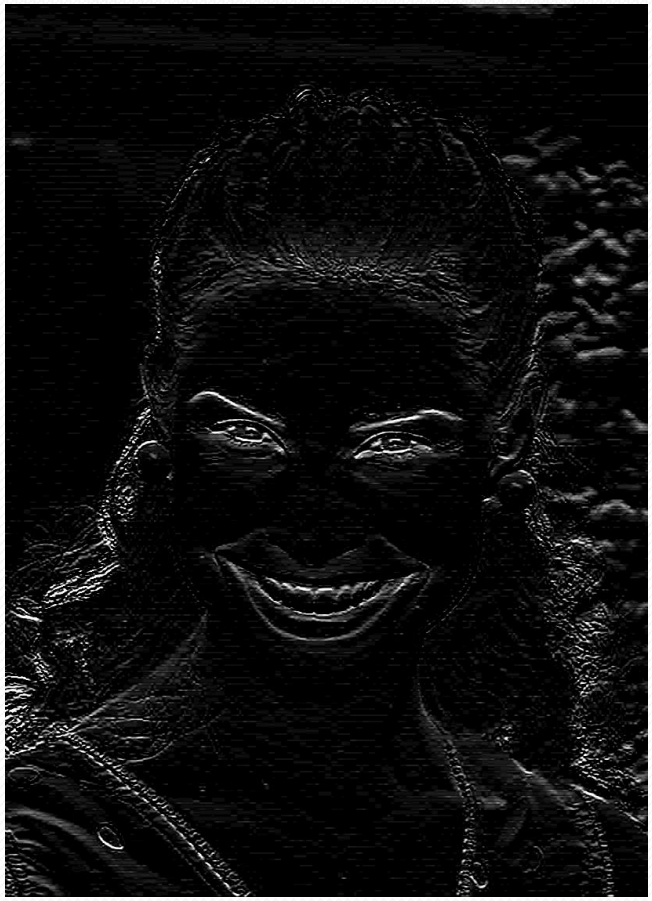


Horizontal Prewitt filter



Vertical Prewitt filter

Edge detection filters



Horizontal filter effect

Vertical filter effect

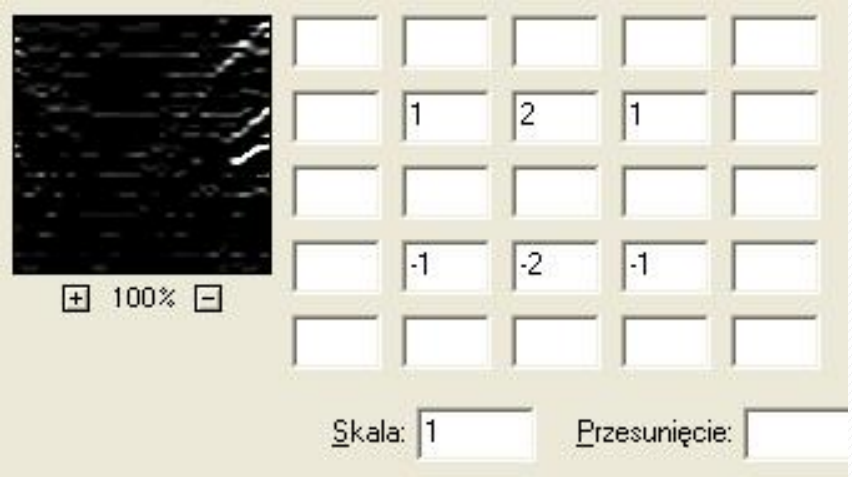
Edge detection filters

Sobel operators

Similarly as Prewitt filters are based on gradient analysis, although they operate on higher values of coefficients. They give the clearer effect, and the detected edges usually are thicker.

Due to the higher sensitivity they error rate is higher (edges erroneously detected as a result of disturbances in the image).

Edge detection filters



Horizontal Sobel filter

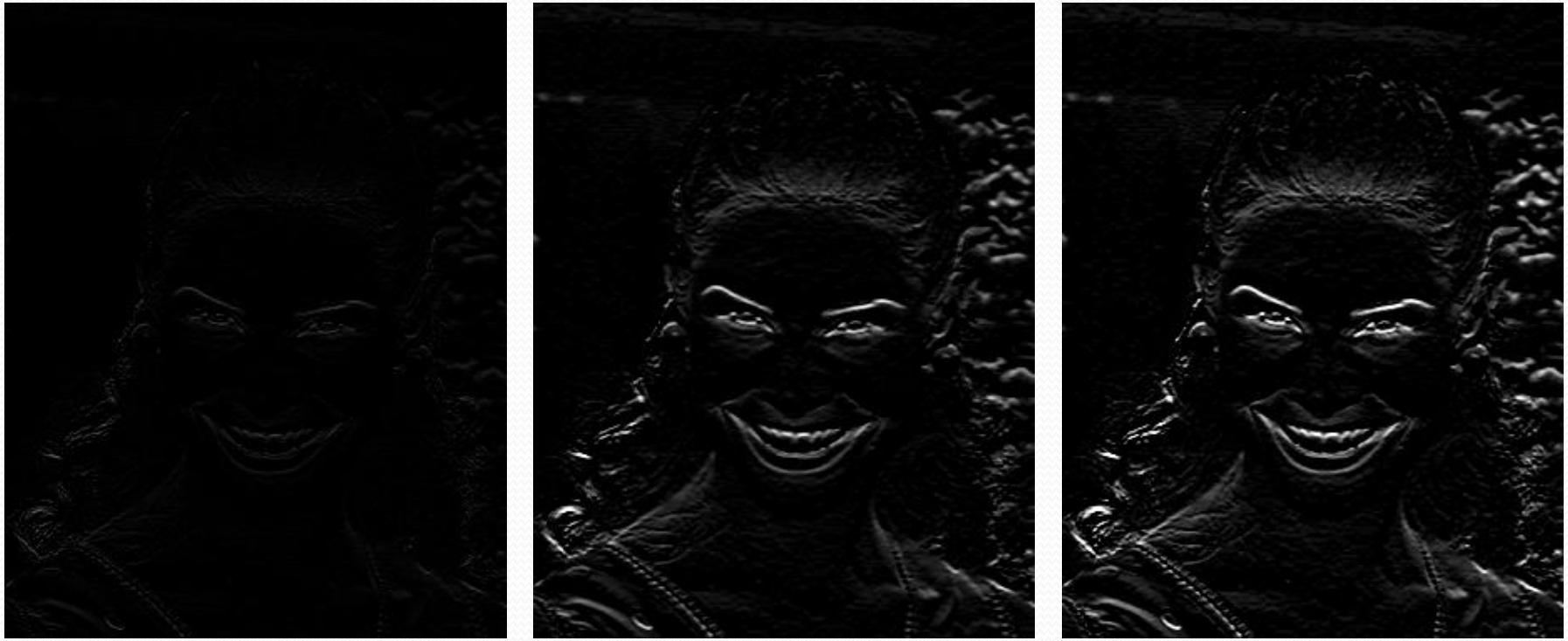
Vertical Sobel filter

Edge detection filters

Horizontal filter effect

Vertical filter effect

Edge detection filters



Comparison of filters: Roberts, Prewitt and Sobel

Edge detection filters

Laplace filters

They are used to detect and extract all edges regardless of their direction (non-directional).

Built based on the sum of derivative functions of the brightness gradient for horizontal and vertical directions, or for all directions (including diagonal directions).

Examples:

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

LAPL1

-1	-1	-1
-1	8	-1
-1	-1	-1

LAPL2

-2	1	-2
1	4	1
-2	1	-2

LAPL3

Edge detection filters

Laplace filters

-1	2	-1
-1	2	-1
-1	2	-1

+

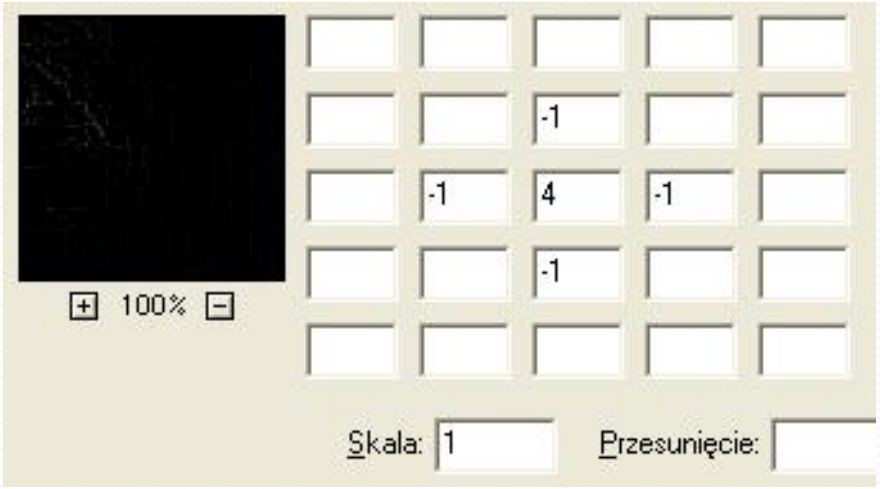
-1	-1	-1
2	2	2
-1	-1	-1

=

-2	1	-2
1	4	1
-2	1	-2

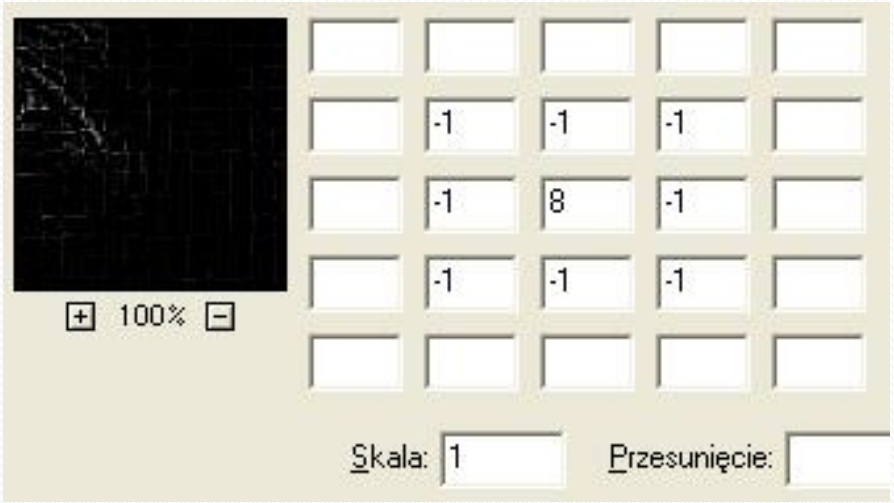
Combining of two filters detecting the edges – horizontal and vertical.

Edge detection filters



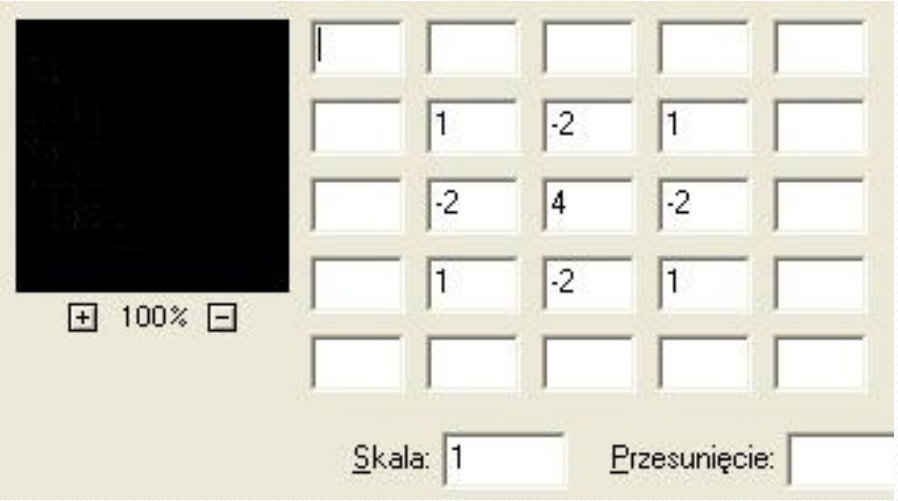
LAPL1 filter

Edge detection filters

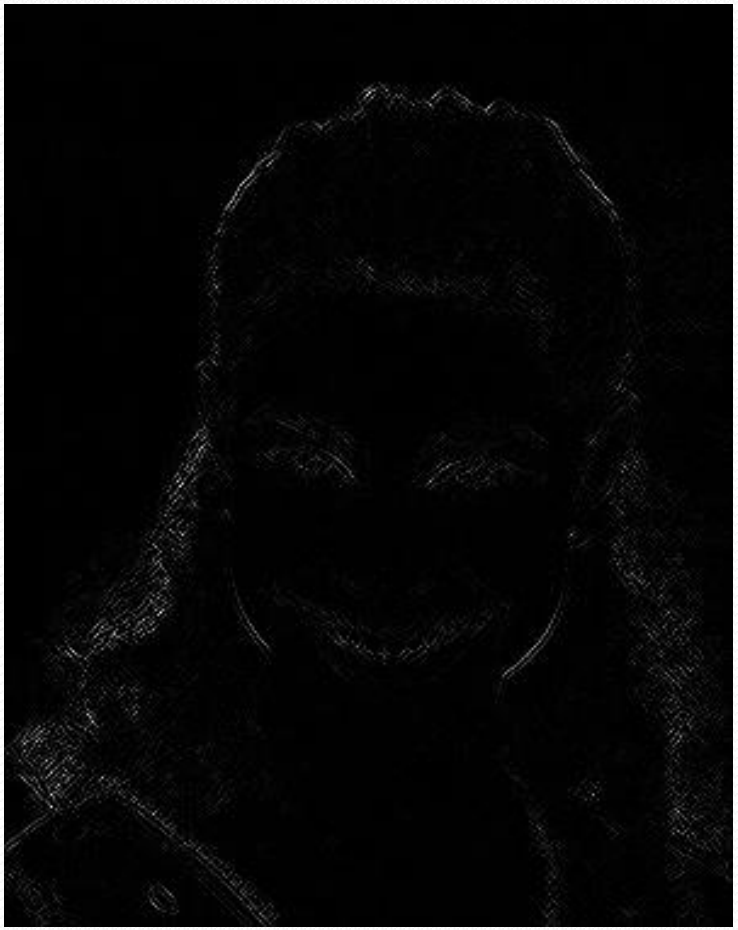


LAPL2 filter

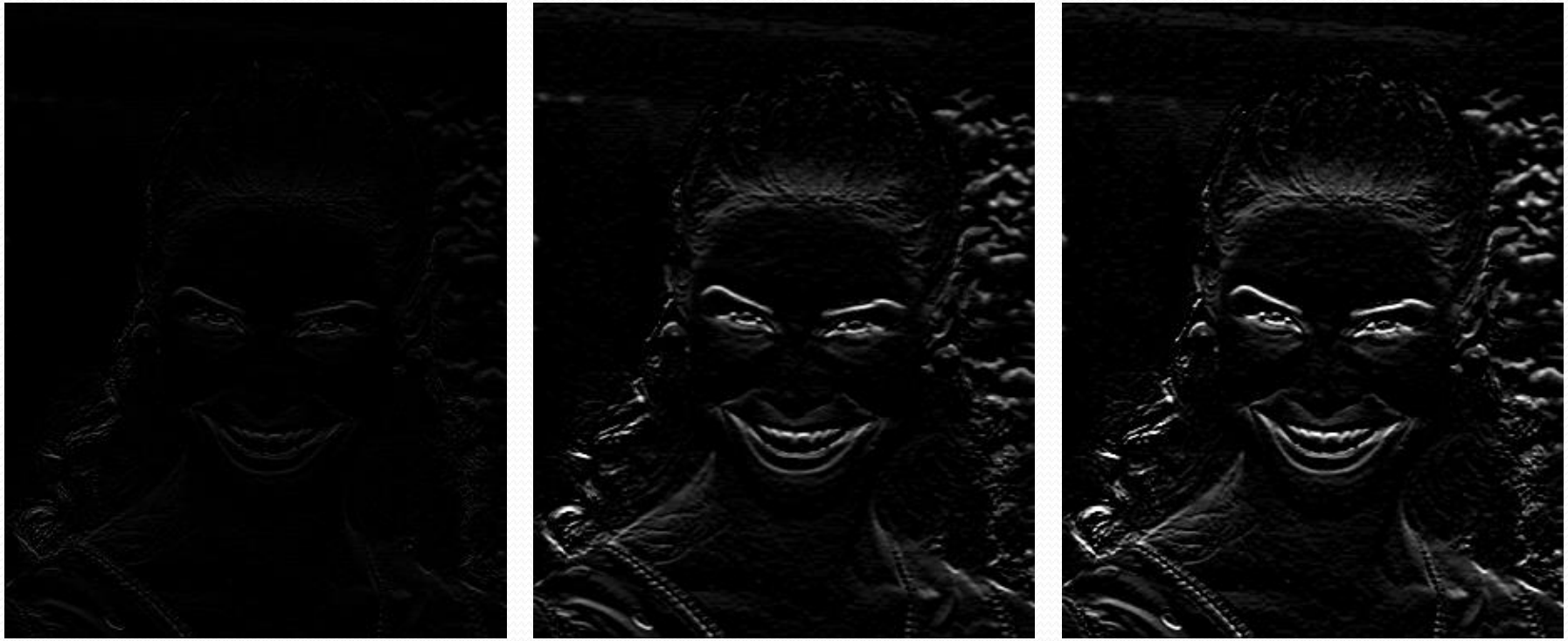
Edge detection filters



LAPL3 filter



Edge detection filters



Comparison of filters: LAPL1, LAPL2 and LAPL3.

Edge detection filters

-1	-1	-1
-1	8	-1
-1	-1	-1

+

0	0	0
0	1	0
0	0	0

=

-1	-1	-1
-1	9	-1
-1	-1	-1

Comparison of LAPL2 filter and the highpass sharpening filter.

Corner detection filters

Robinson kernels

$$\begin{matrix} 1 & 1 & 1 \\ 1 & -2 & -1 \\ 1 & -1 & -1 \end{matrix}$$
135^0

$$\begin{matrix} 1 & 1 & 1 \\ 1 & -2 & 1 \\ -1 & -1 & -1 \end{matrix}$$
90^0

$$\begin{matrix} 1 & 1 & 1 \\ -1 & -2 & 1 \\ -1 & -1 & 1 \end{matrix}$$
45^0

$$\begin{matrix} 1 & 1 & -1 \\ 1 & -2 & -1 \\ 1 & 1 & -1 \end{matrix}$$
180^0

$$\begin{matrix} -1 & 1 & 1 \\ -1 & -2 & 1 \\ -1 & 1 & 1 \end{matrix}$$
0^0

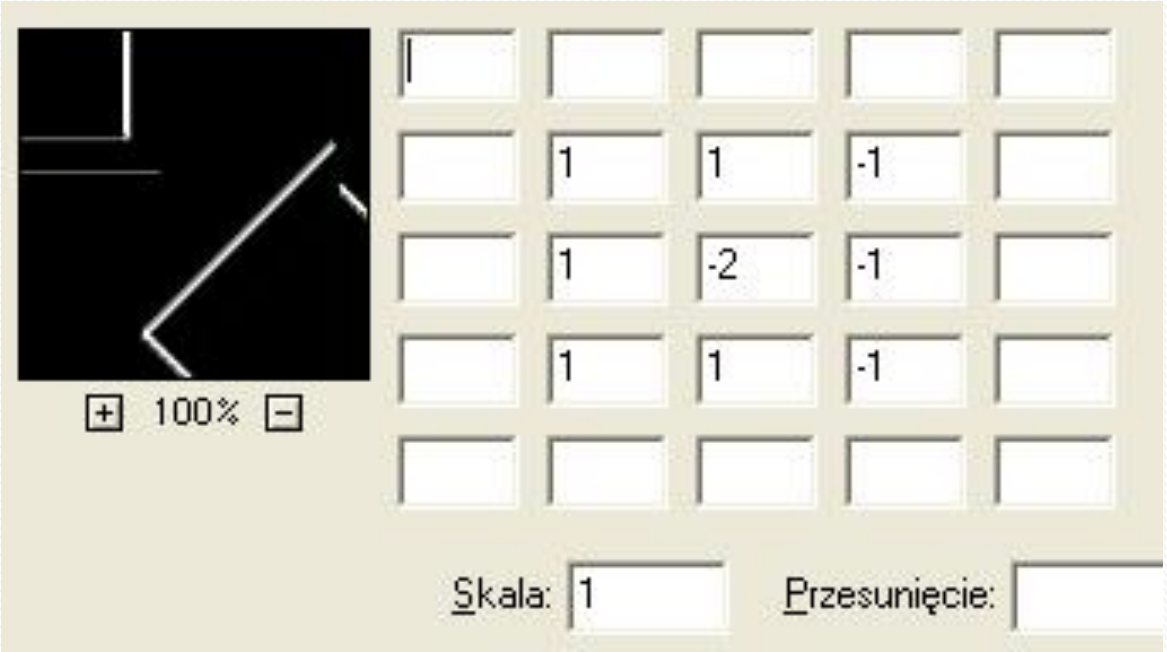
$$\begin{matrix} 1 & -1 & -1 \\ 1 & -2 & -1 \\ 1 & 1 & 1 \end{matrix}$$
225^0

$$\begin{matrix} -1 & -1 & -1 \\ 1 & -2 & 1 \\ 1 & 1 & 1 \end{matrix}$$
270^0

$$\begin{matrix} -1 & -1 & 1 \\ -1 & -2 & 1 \\ 1 & 1 & 1 \end{matrix}$$
315^0

Corner detection filters

Robinson kernels



Robinson kernel detecting corners for the 180° direction

Nonlinear filters

When using linear filters, you aren't always achieve all the goals you have set. Sometimes it is necessary to apply more complicated methods, such as non-linear filters, whose properties and usefulness are very often evaluated experimentally.

The most important nonlinear filters are:

- median,
- minimal,
- maximal.

Nonlinear filters

Median filter

Often, in order to filter the image, kernels that take as a result the value of one of the surrounding pixels are used.
In the median filter, the median value from the orderly sequence of the brightness values of the neighbouring pixels is used. Noise reduction is achieved by eliminating pixels whose value deviates significantly from the average value of other pixels.
Because new values do not appear during filtering, there is no need to normalize the image (scaling brightness), the edges are essentially preserved.
The disadvantage of the median is the elimination of the corners.

Nonlinear filters

Median filter

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

10 11 13 14 21 28 39 42 65

24	35	16	21	42	65
25	30	14	13	21	

- Lowpass averaging filter

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	13	27	

Nonlinear filters

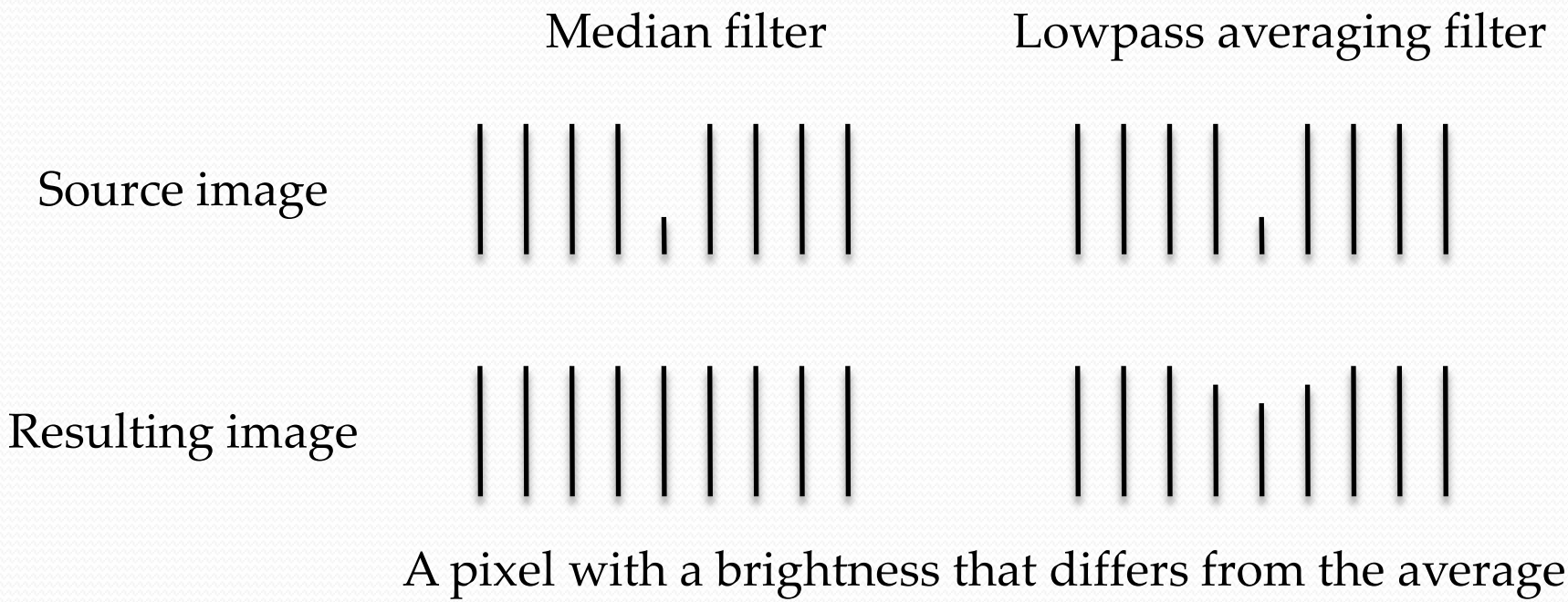
Median filter

Source image

Image after filtering

Nonlinear filters

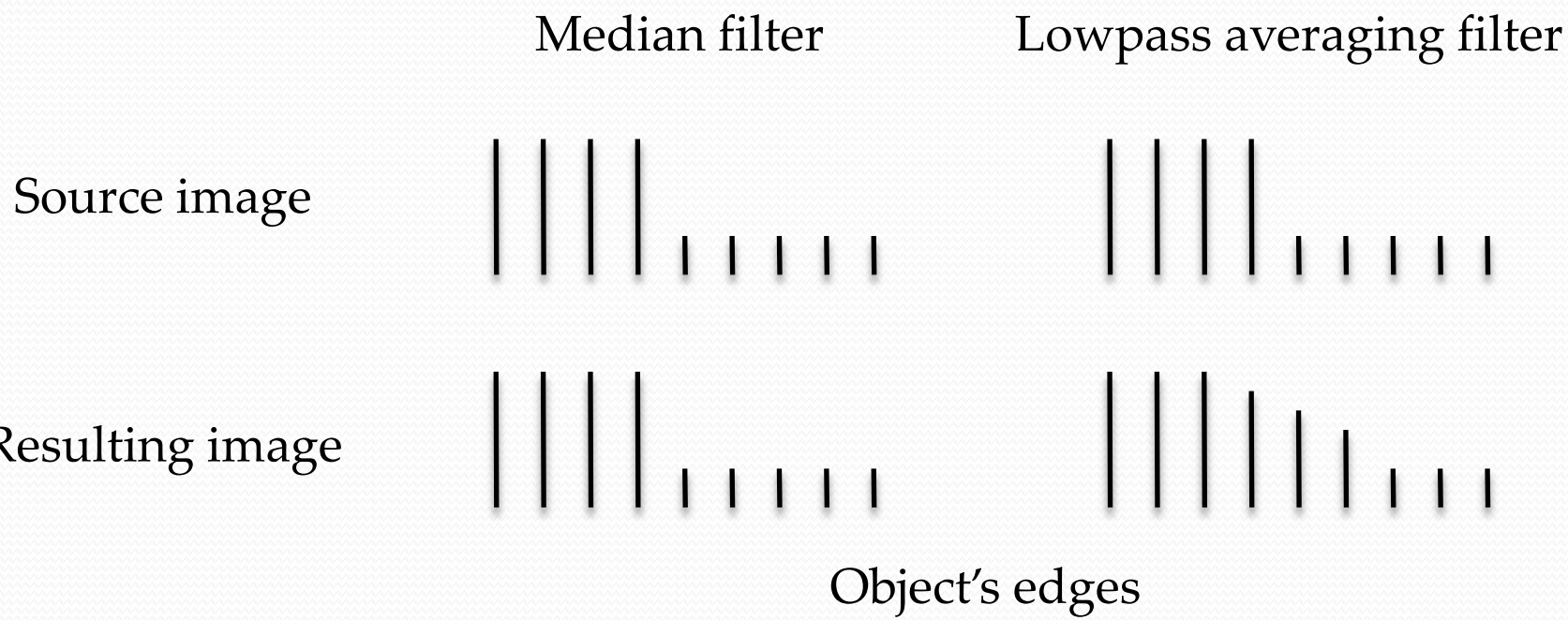
Median filter



A pixel with a brightness that differs from the average

Nonlinear filters

Median filter



Nonlinear filters

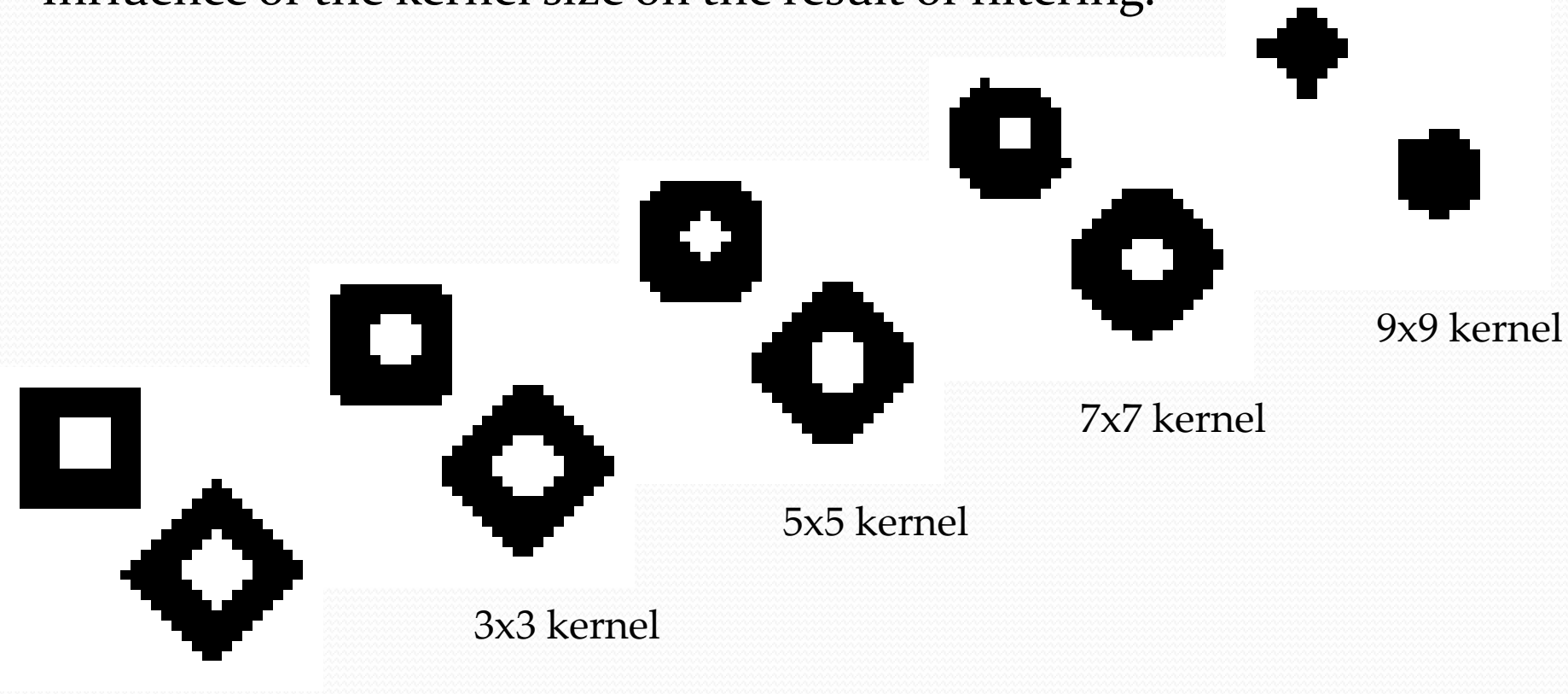
Lowpass averaging filter

Median filter

Nonlinear filters

Median filter

Influence of the kernel size on the result of filtering.



Nonlinear filters

Minimal filter

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

10 11 13 14 21 28 39 42 65

24	35	16	21	42	65
25	30	14	13	10	

Nonlinear filters

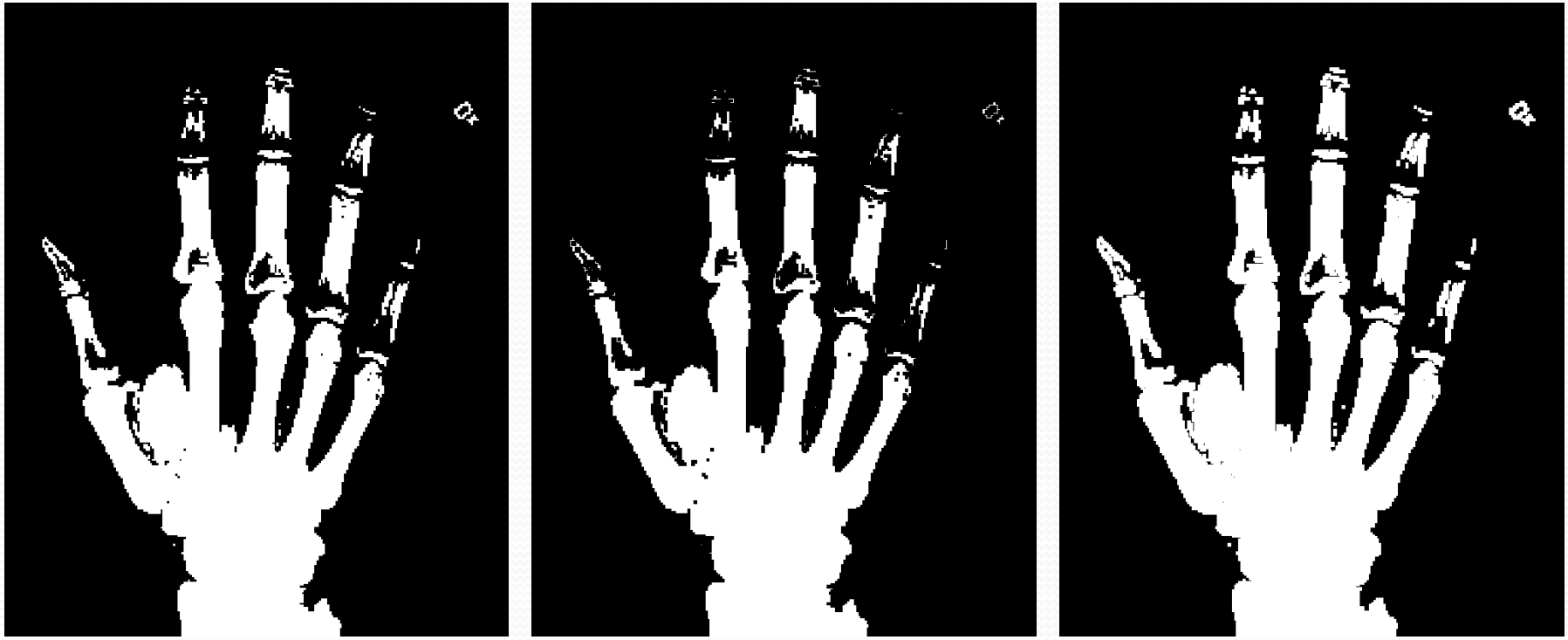
Maximal filter

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

10 11 13 14 21 28 39 42 65

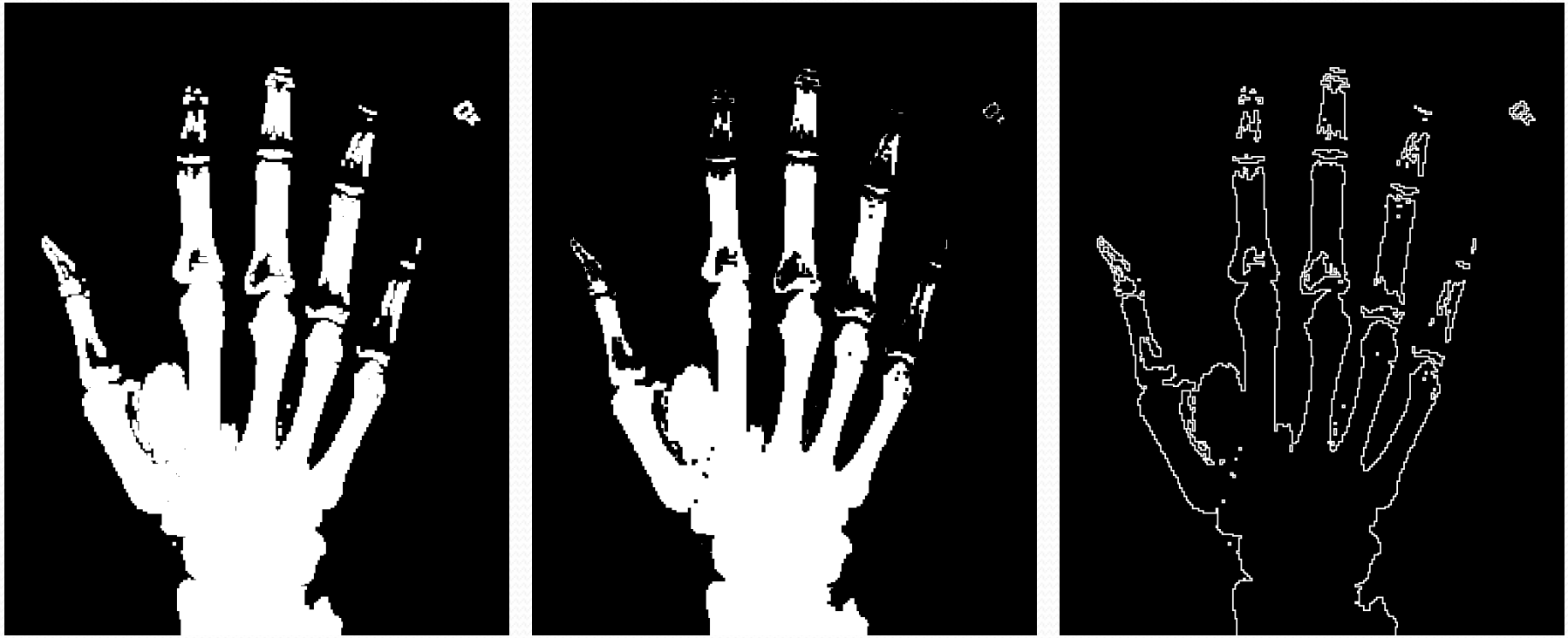
24	35	16	21	42	65
25	30	14	13	65	

Nonlinear filters



Source image and the result of filtering with the use of minimal and maximal filter.

Nonlinear filters



Contour of the object achieved as a result of calculating difference between minimal and maximal filters used.