PODSTAWY PRZETWARZANIA OBRAZÓW CYFROWYCH

Przekształcenia kontekstowe

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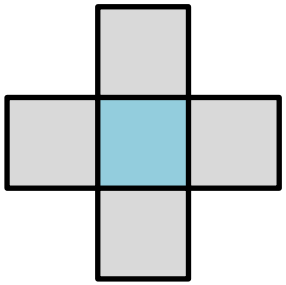
Przekształcenia kontekstowe

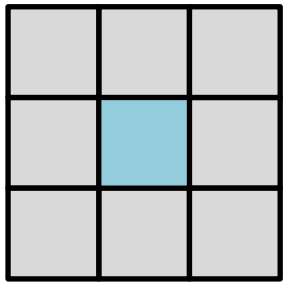
- Sąsiedztwo piksela
- Filtry liniowe
  - filtry splotowe (konwolucyjne)
    - kierunkowe, uśredniające, wyostrzające, dolnoprzepustowe/górnoprzepustowe,
    - filtry Robertsa, Prewitta, Sobela, laplasjany, Gaussa,
- Kombinacje filtrów
  - Laplacian of Gaussian, Difference of Gaussian,
    - Mexican Hat (blob detection)
- Filtry nieliniowe
  - filtry rankingowe
    - mediana, min, max
- Inne operacje kontekstowe
  - AHE (CLAHE) ….

Sąsiedztwo piksela

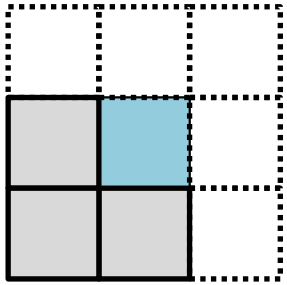
złożoność obliczeniowa!



4-connected

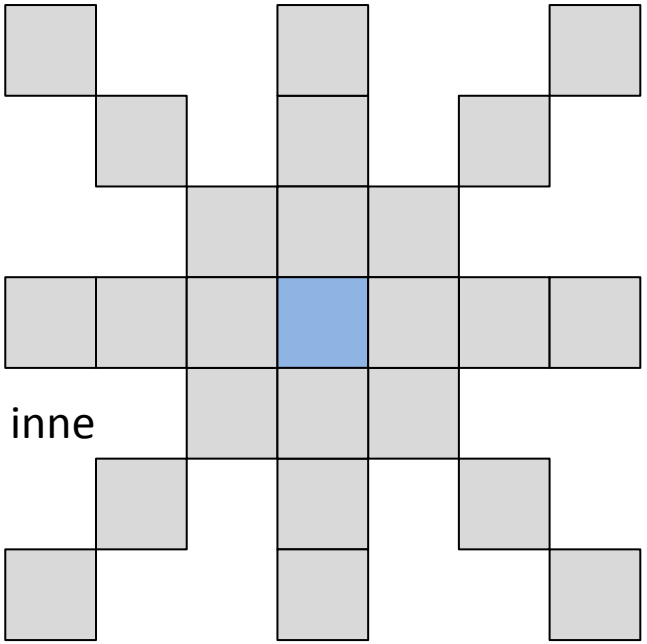


8-connected
3x3

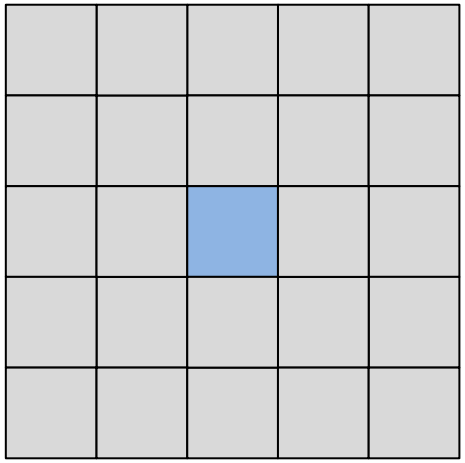


2x2
niezalecane

O (4r)

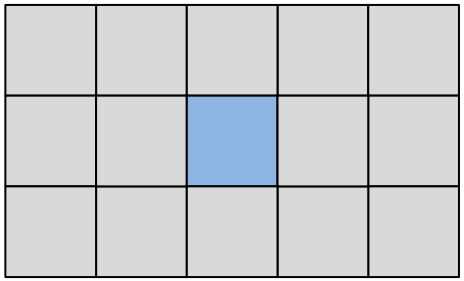


inne



kwadrat
5x5

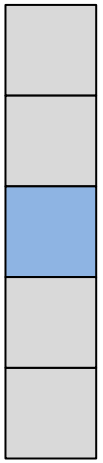
O(r²)



prostokąt
5x3

*O (r_a*r_b)*

f. kierunkowe

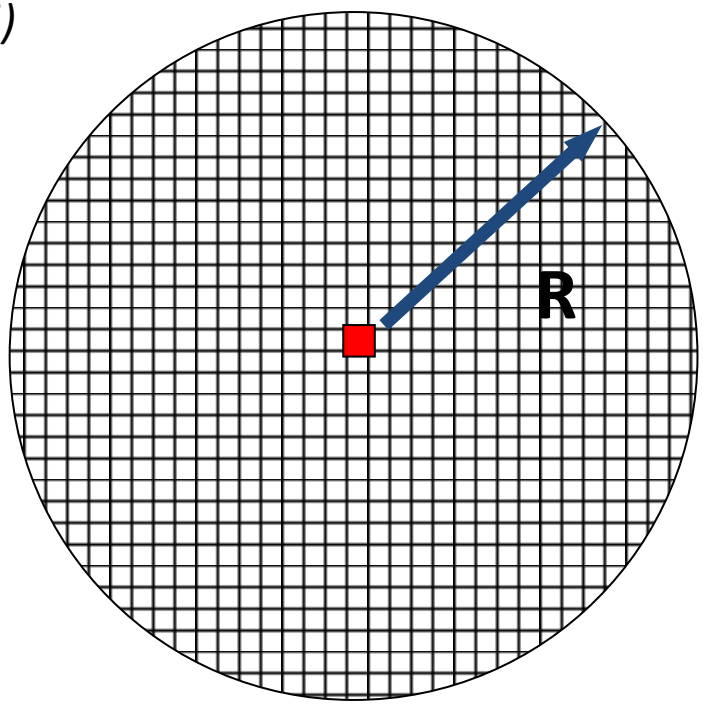


O (r)

Sąsiedztwo piksela

$rx^2 + ry^2 <= R^2$

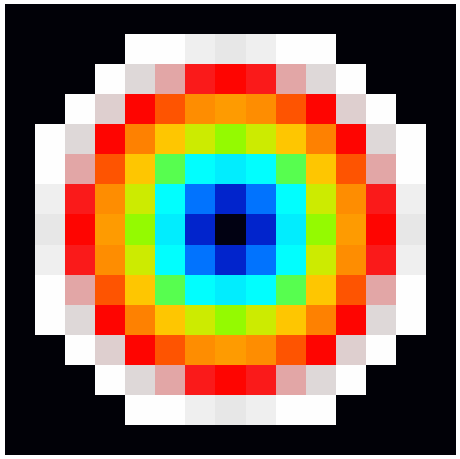
$O(r^2)$



5.7	5.0	4.5	4.1	4.0	4.1	4.5	5.0	5.7
5.0	4.2	3.6	3.2	3.0	3.2	3.6	4.2	5.0
4.5	3.6	2.8	2.2	2.0	2.2	2.8	3.6	4.5
4.1	3.2	2.2	1.4	1.0	1.4	2.2	3.2	4.1
4.0	3.0	2.0	1.0	**R**	1.0	2.0	3.0	4.0
4.1	3.2	2.2	1.4	1.0	1.4	2.2	3.2	4.1
4.5	3.6	2.8	2.2	2.0	2.2	2.8	3.6	4.5
5.0	4.2	3.6	3.2	3.0	3.2	3.6	4.2	5.0
5.7	5.0	4.5	4.1	4.0	4.1	4.5	5.0	5.7

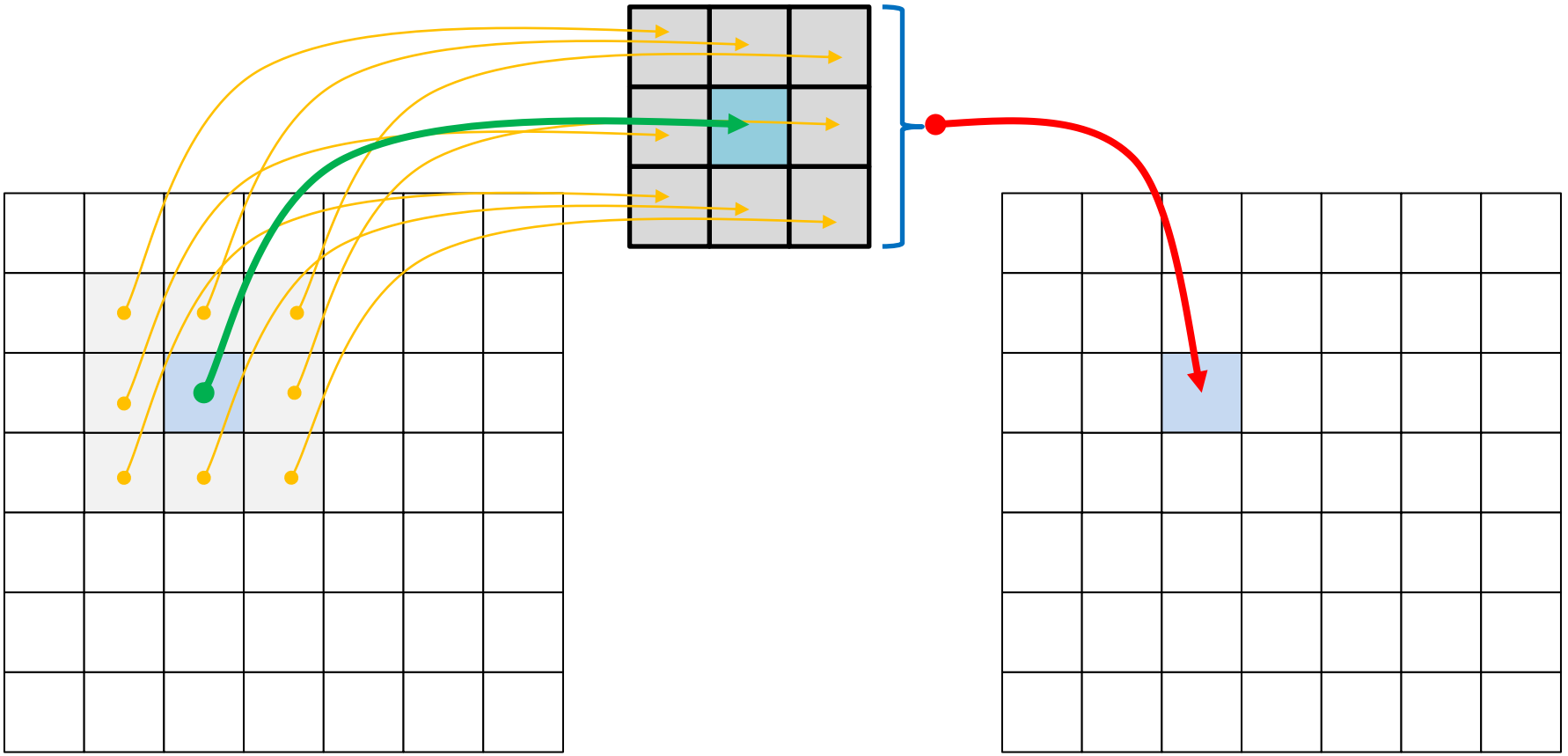
zaokrąglone do 0.1 !

$1.4 < 1.41 < \sqrt{2}$



Rozmiar maski istotny – dla obrazu o innym rozmiarze (powiększonego, pomniejszonego) ten sam filtr może działać inaczej

Przekształcenia kontekstowe



0	0	0	0	0	0	0	0	10	90	90	90	90	90	90	90
0	0	0	0	0	0	0	10	80	90	90	90	90	90	90	90
0	0	10	20	0	0	10	80	90	90	90	90	80	0	90	90
0	0	20	10	0	10	80	90	90	90	80	0	0	20	90	90
0	0	10	0	0	80	80	90	90	80	10	0	0	0	90	90
0	0	0	0	20	80	90	90	90	80	20	0	0	0	90	90
0	10	0	0	80	90	90	90	90	80	80	0	0	80	90	90
0	0	0	80	90	90	90	90	90	90	20	80	0	10	90	90
0	0	20	90	90	90	90	90	90	80	20	80	80	0	90	90
0	0	80	90	90	90	90	90	90	30	90	90	90	90	90	90
0	80	90	90	90	20	90	90	90	90	90	90	90	90	90	90
90	90	90	90	20	20	20	90	90	90	90	90	90	90	90	90
90	90	90	20	20	10	20	30	90	90	90	90	70	80	90	90
90	90	90	80	20	20	20	30	90	90	90	90	60	70	80	90
90	90	90	90	20	30	20	80	90	90	90	90	90	90	80	90
90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90

3	3	3	3	3	3	3
3	2	2	2	2	2	3
3	2	1	1	1	2	3
3	2	1	0	1	2	3
3	2	1	1	1	2	3
3	2	2	2	2	2	3
3	3	3	3	3	3	3

r=3.75, t=50

3	3	3	3	3	3	3
3	2	2	2	2	2	3
3	2	1	1	1	2	3
3	2	1	0	1	2	3
3	2	1	1	1	2	3
3	2	2	2	2	2	3
3	3	3	3	3	3	3

suma = 45

0	0	0	0	2	5	9	14	20	0	0	0	0	0	0	0
0	0	0	2	5	9	14	20	0	0	0	0	0	0	0	0
0	0	1	4	8	13	19	0	0	0	0	0	0	34	0	0
0	0	3	7	12	18	0	0	0	0	0	31	31	31	0	0
0	2	6	11	17	0	0	0	0	0	29	28	28	29	0	0
1	4	9	15	21	0	0	0	0	0	28	26	26	27	0	0
3	7	13	19	0	0	0	0	0	0	0	26	27	0	0	0
6	11	17	0	0	0	0	0	0	0	30	0	29	31	0	0
11	16	20	0	0	0	0	0	0	0	34	0	0	35	0	0
15	19	0	0	0	0	0	0	0	38	0	0	0	0	0	0
21	0	0	0	0	31	0	0	0	0	0	0	0	0	0	0
0	0	0	0	26	29	28	0	0	0	0	0	0	0	0	0
0	0	0	27	29	29	29	29	0	0	0	0	0	0	0	0
0	0	0	0	29	29	29	30	0	0	0	0	0	0	0	0
0	0	0	0	30	30	30	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0
0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0
0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0
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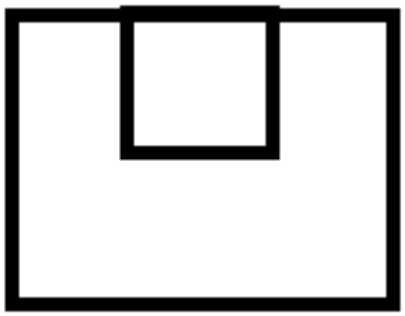
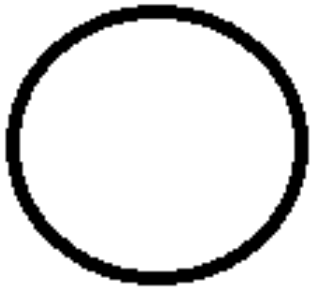
0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0
0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0
0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

b=25

Nurzynska, K., Mikhalkin, A., Piorkowski, A.:
CAS: Cell Annotation Software - Research on Neuronal Tissue Has Never Been so Transparent.
Neuroinformatics, 2017, Vol. 15, Iss. 4, pp 365-382.

Sąsiedztwo - artefakty





+

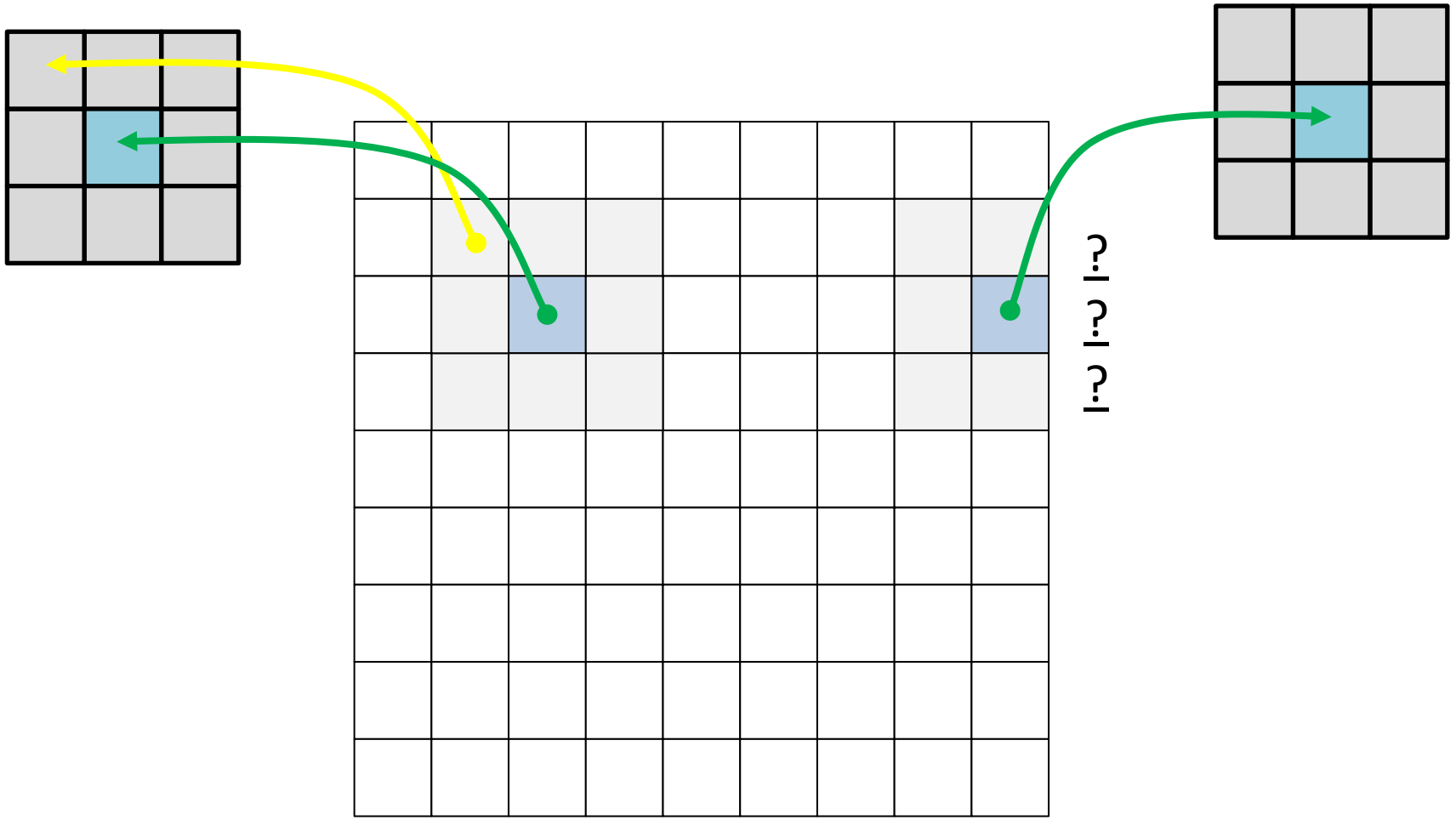
o

[ ]

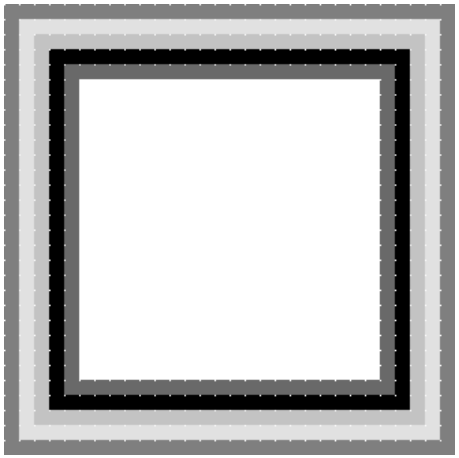
*

Sąsiedztwo - artefakty

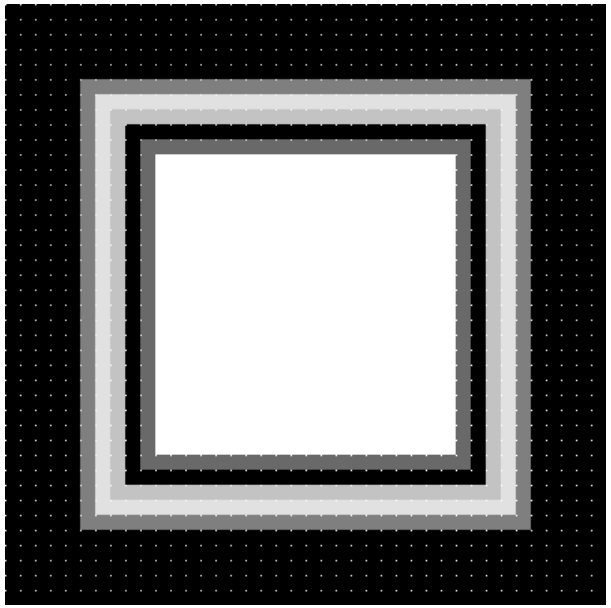
A co z marginesami?



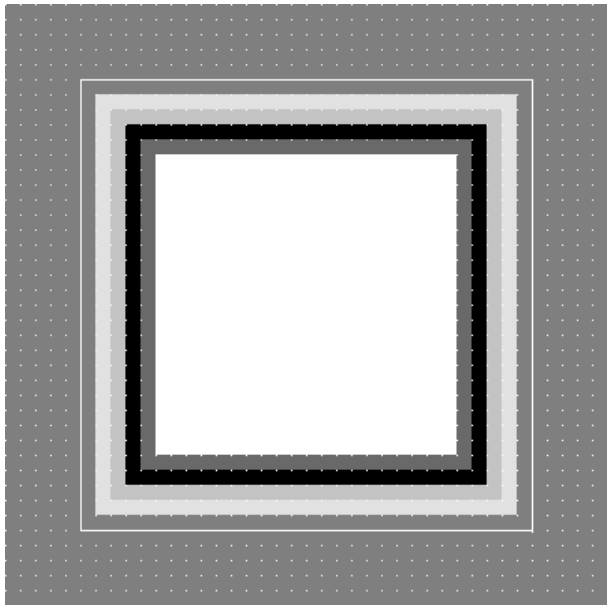
A co z marginesami?



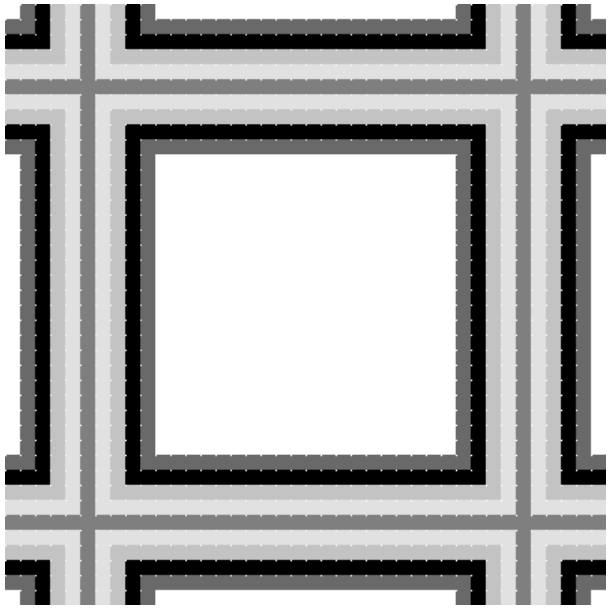
margines 5 pikseli



wypełnienie zerami

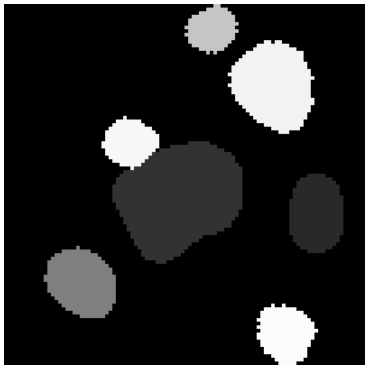


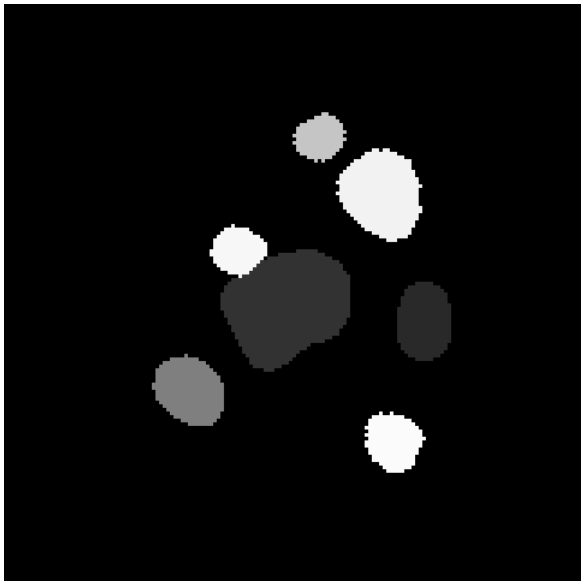
kopia brzegu



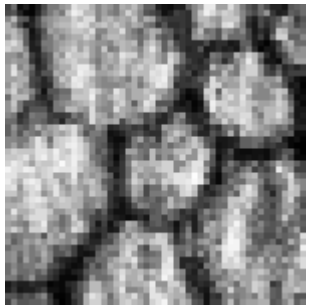
kopia lustrzana

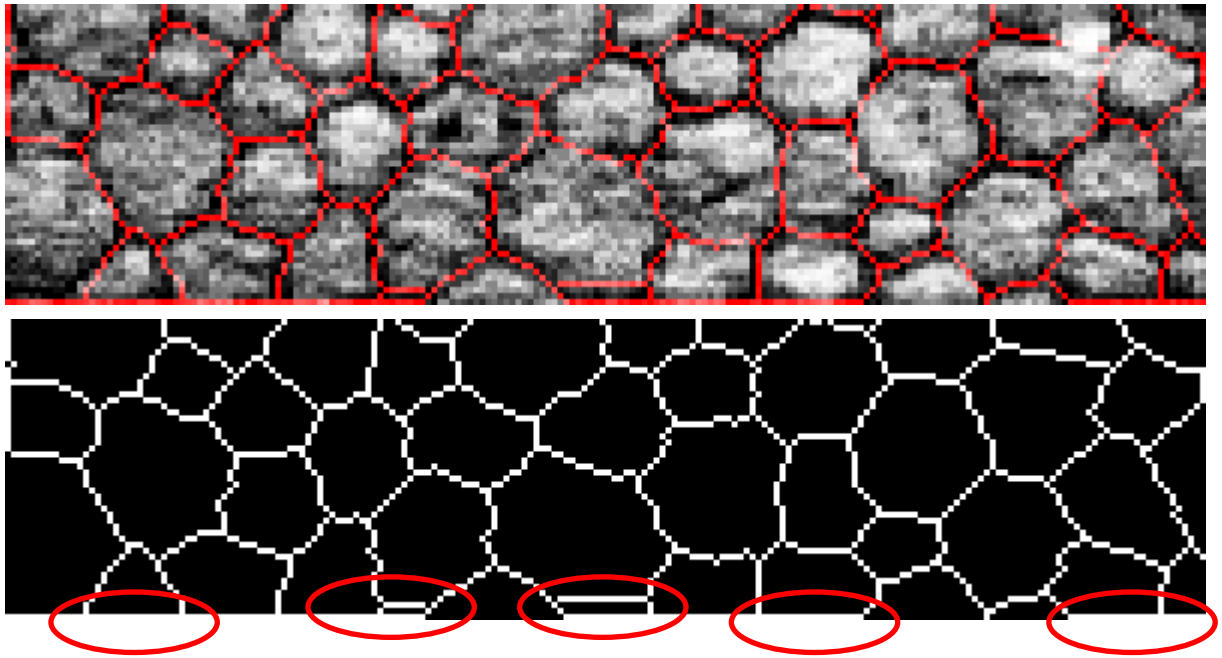
A co z marginesami?

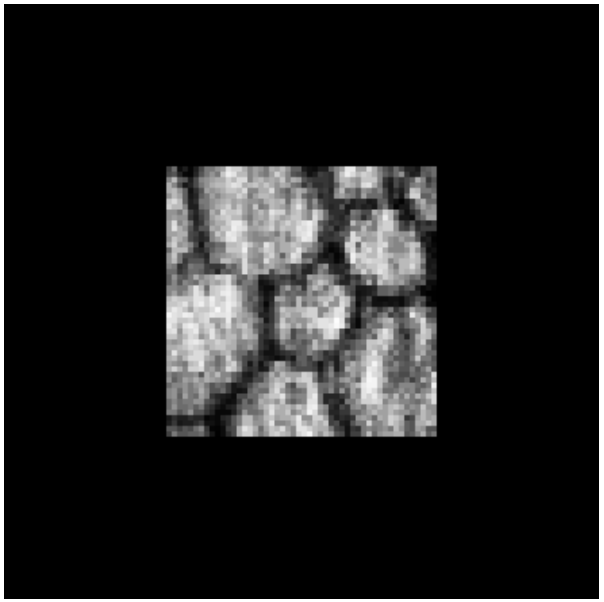


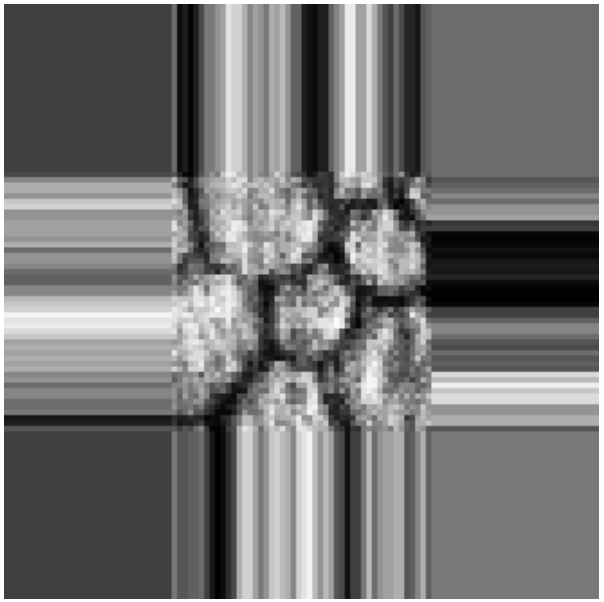


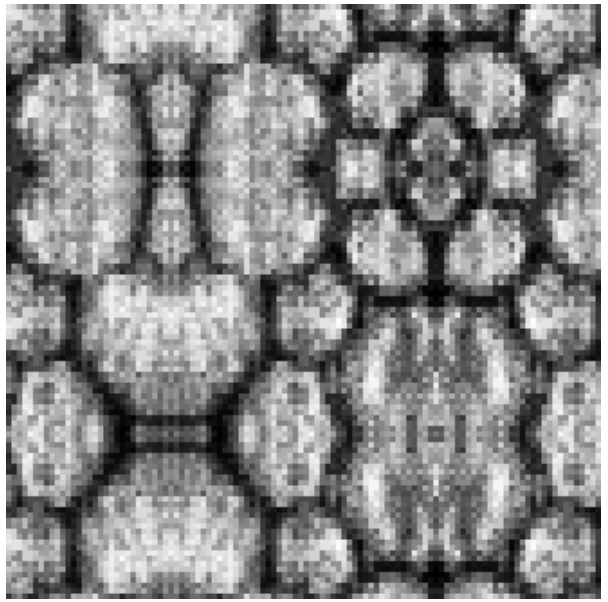
A co z marginesami?











```
// marginesy lustrzane, 2021.11.13, AP

Marg = 30;            // rozmiar marginesu

w = getWidth();
h = getHeight();

Marg = minOf(Marg, w-1);         // margines nie moze byc wiekszy niz rozmiar obrazu
Marg = minOf(Marg, h-1);         // margines nie moze byc wiekszy niz rozmiar obrazu

tytul =  File.getNameWithoutExtension(getTitle()) +"_marg_" + Marg;


// zaladowanie obrazu do tablicy
obraz = newArray(w*h);

for (y=0; y<h; y++)
          for (x=0; x<w; x++)
                    obraz[x + y *w] = getPixel(x, y);

// stworzenie nowego obrazu wiekszego o margines

obraz_nowy = newArray( (w + Marg * 2) * (h + Marg * 2) );
Array.fill(obraz_nowy,  0);

// kopiowanie czesci zasadniczej
for (i =  0; i < w; i++)
          for (j =  0; j < h; j++)
                    obraz_nowy[(i + Marg) + (w + Marg * 2) * (j + Marg)] =  obraz[i + w * j];


// ##############################################
// utworzenie nowego obrazka - marginesy wypelnione zerami
newImage(tytul + "_zero", "8-bit", w + Marg * 2, h + Marg * 2, 1);
for (y=0; y < h + Marg * 2; y++)
          for (x=0; x < w + Marg * 2; x++)
                    setPixel(x, y, obraz_nowy[x + y *(w + Marg * 2)] );
```

```
// marginesy lustrzane, 2021.11.13, AP     - c.d.

// ##############################################
// utworzenie nowego obrazka - marginesy wypelnione wartosciami brzegowymi

// kopiowanie marginesow
// gorny i dolny
for (i =  0; i < w; i++)
{
  for (k =  0; k <= Marg; k++)
  {
  obraz_nowy[i + Marg + (Marg - k)*(w + Marg * 2)] = obraz[i + w *  0];
  obraz_nowy[i + Marg + (h - 1 + Marg + k) * (w + Marg * 2)] = obraz[i + w* ( h - 1 )];
  }
}
// prawy i lewy
for (j =  0; j < h; j++)
{
  for (k =  0; k <= Marg; k++)
  {
  obraz_nowy[Marg - k + (j + Marg) *(w + Marg * 2)] = obraz[0*k + w * j];
  obraz_nowy[w - 1 + Marg + k + (j + Marg) *(w + Marg * 2)] = obraz[w - 1 -  0*k + w * j];
  }
}

// kopiowanie naroznikow
for (i =  0; i <= Marg; i++)
  for (j =  0; j <= Marg; j++)
  {
  obraz_nowy[Marg - i + (w + Marg * 2)*( Marg - j)] = obraz[0];
  obraz_nowy[w - 1 + Marg + i + (w + Marg * 2)*( Marg - j)] = obraz[w - 1];
  obraz_nowy[Marg - i + (w + Marg * 2)*(h - 1 + Marg + j)] = obraz[w*( h - 1)];
  obraz_nowy[w - 1 + Marg + i + (w + Marg * 2)*(h - 1 + Marg + j)] = obraz[w - 1 + w *( h - 1 )];
  }

newImage(tytul + "_brzeg", "8-bit", w + Marg * 2, h + Marg * 2, 1);
for (y=0; y < h + Marg * 2; y++)
           for (x=0; x < w + Marg * 2; x++)
                     setPixel(x, y, obraz_nowy[x + y *(w + Marg * 2)] );
```

```
// marginesy lustrzane, 2021.11.13, AP      - c.d. 2

// ##############################################
// utworzenie nowego obrazka - marginesy lustrzane

// kopiowanie marginesow
// gorny i dolny
for (i =  0; i < w; i++)
{
  for (k =  0; k <= Marg; k++)
  {
    obraz_nowy[i + Marg + (Marg - k)*(w + Marg * 2)] = obraz[i + w * k];
    obraz_nowy[i + Marg + (h - 1 + Marg + k) * (w + Marg * 2)] = obraz[i + w*( h - 1 - k)];
  }
}
// prawy i lewy
for (j =  0; j < h; j++)
{
  for (k =  0; k <= Marg; k++)
  {
    obraz_nowy[Marg - k + (j + Marg) *(w + Marg * 2)] = obraz[k + w * j];
    obraz_nowy[w - 1 + Marg + k + (j + Marg) *(w + Marg * 2)] = obraz[w - 1 - k + w * j];
  }
}

// kopiowanie naroznikow
for (i =  0; i <= Marg; i++)
  for (j =  0; j <= Marg; j++)
  {
    obraz_nowy[Marg - i + (w + Marg * 2)*( Marg - j)] = obraz[i + w * j];
    obraz_nowy[w - 1 + Marg + i + (w + Marg * 2)*( Marg - j)] = obraz[w - 1 - i + w * j];
    obraz_nowy[Marg - i + (w + Marg * 2)*(h - 1 + Marg + j)] = obraz[i + w*( h - 1 - j)];
    obraz_nowy[w - 1 + Marg + i + (w + Marg * 2)*(h - 1 + Marg + j)] = obraz[w - 1 - i + w *( h - 1 - j)];
  }

newImage(tytul + "_lustro", "8-bit", w + Marg * 2, h + Marg * 2, 1);
for (y=0; y < h + Marg * 2; y++)
    for (x=0; x < w + Marg * 2; x++)
        setPixel(x, y, obraz_nowy[x + y * (w + Marg * 2)] );
```

Filtry konwolucyjne (splotowe)

$$g(x) = (f \times h)(x) = \int_{-\infty}^{+\infty} f(x-t)h(t)dt$$

$$P'(m,n) = (w \times P)(m,n) = \sum_{i,j \in K} P(m-i, n-j)w(i,j)$$

$$w(i,j) = \begin{bmatrix} w_{-1,-1} & w_{0,-1} & w_{1,-1} \\ w_{-1,0} & w_{0,0} & w_{1,0} \\ w_{-1,1} & w_{0,1} & w_{1,1} \end{bmatrix}$$

Filtry są liniowe, gdy sa opisane funkcją:
- addytywną: $\varphi(f+g) = \varphi(f) + \varphi(g)$,
- jednorodną: $\varphi(\lambda f) = \lambda\, \varphi(f)$.

Filtry konwolucyjne (splotowe)

Kontrola zakresu wartości uzyskiwanych przy konwolucji

Dla współczynników nieujemnych: (co najmniej jeden większy od zera)

$$n = \frac{1}{\sum_{i,j \in K} w(i,j)}$$

$$P'(m,n) = \frac{1}{\sum_{i,j \in K} w(i,j)} \sum_{i,j \in K} P(m-i, n-j) w(i,j)$$

Dla współczynników dowolnych:

- skalowanie obrazu po konwolucji z zakresu (*min,max*) do (0,255) (normalizacja)
  - przesunięcie tła!
- ujemne - wyznaczenie wartości bezwzględnej z otrzymanego obrazu,
- limitowanie wartości wykraczających poza zakres (0,255)
  - niejawna binaryzacja

Filtry dolnoprzepustowe

0	1	0
1	1	1
0	1	0

1	1	1
1	1	1
1	1	1

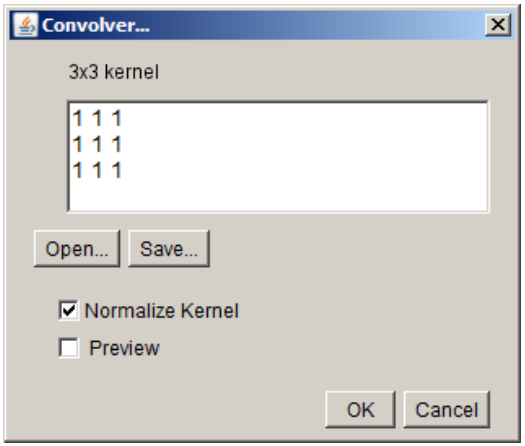
klasyczne filtry uśredniające

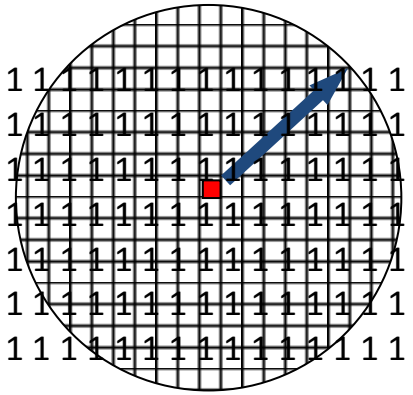
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1

1	2	1
2	4	2
1	2	1

1	3	1
3	9	3
1	3	1

aproksymacja rozkładu Gaussa





Filtry dolnoprzepustowe:
+ redukują szum (wysokie częstotliwości),
+ wygładzają obraz,
- rozmywają krawędzie

Filtry górnoprzepustowe

- Gradienty (kierunkowe): (aproksymacja I pochodnej)
  - gradient Robertsa, maski Prewitta, Sobela,
- Laplasjany (bezkierunkowe) (suma drugich pochodnych cząstkowych)
- Maski wykrywające narożniki (i inne kształty)
  - maski Robinsona, Kircha, …

Gradient Robertsa

G_1

	1	0
	0	-1

G_2

	0	1
	-1	0

$$G = \sqrt{G_1^2 + G_2^2}$$

$$G = |G_1| + |G_2|$$

$$\Theta = \arctan(\frac{G_1}{G_2})$$

maski 2x2 nie oddają symetrycznego położenia punktu centralnego – powstaje przesunięcie w obrazie

Operatory Prewitta

1	**1**	0
1	0	**-1**
0	**-1**	**-1**

1	**1**	**1**
0	0	0
-1	**-1**	**-1**

0	**1**	**1**
-1	0	**1**
-1	**-1**	0

1	0	**-1**
1	0	**-1**
1	0	**-1**

-1	0	**1**
-1	0	**1**
-1	0	**1**

0	**-1**	**-1**
1	0	**-1**
1	**1**	0

-1	**-1**	**-1**
0	0	0
1	**1**	**1**

-1	**-1**	0
-1	0	**1**
0	**1**	**1**

Operatory Prewitta

-1	**-1**	0
-1	0	**1**
0	**1**	**1**

-1	**-1**	**-1**
0	0	0
1	**1**	**1**

0	**-1**	**-1**
1	0	**-1**
1	**1**	0

-1	0	**1**
-1	0	**1**
-1	0	**1**

1	0	**-1**
1	0	**-1**
1	0	**-1**

0	**1**	**1**
-1	0	**1**
-1	**-1**	0

1	**1**	**1**
0	0	0
-1	**-1**	**-1**

1	**1**	0
1	0	**-1**
0	**-1**	**-1**

jasny obiekt – ciemne tło

Operatory Sobela

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

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

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

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

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

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

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

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

Maski Robinsona (wykrywanie narożników)

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

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

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

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

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

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

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

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

Maski Kircha (wykrywanie narożników)

3	3	3
3	0	-5
3	-5	-5

3	3	3
3	0	3
-5	-5	-5

3	3	3
-5	0	3
-5	-5	3

3	3	-5
3	0	-5
3	3	-5

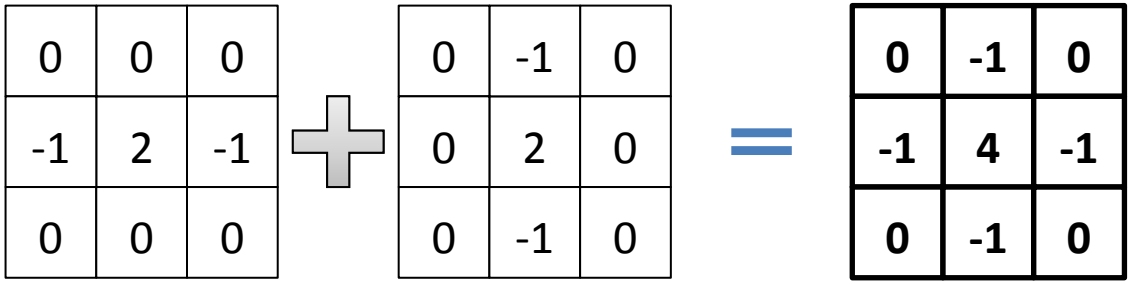
-5	3	3
-5	0	3
-5	3	3

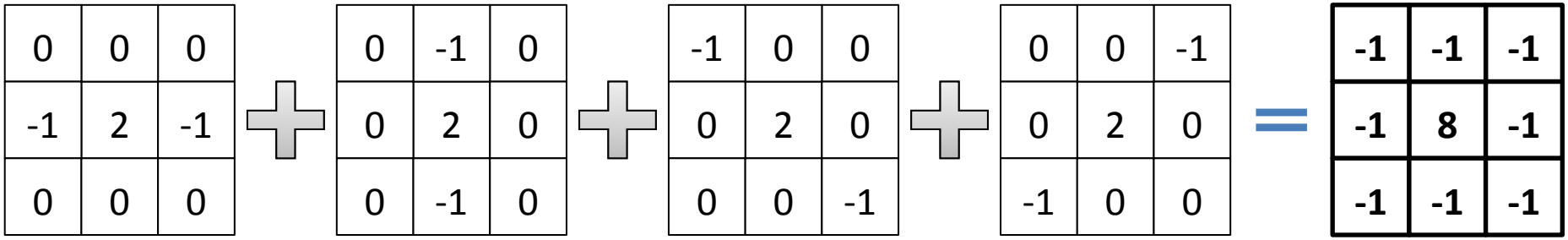
3	-5	-5
3	0	-5
3	3	3

-5	-5	-5
3	0	3
3	3	3

-5	-5	3
-5	0	3
3	3	3

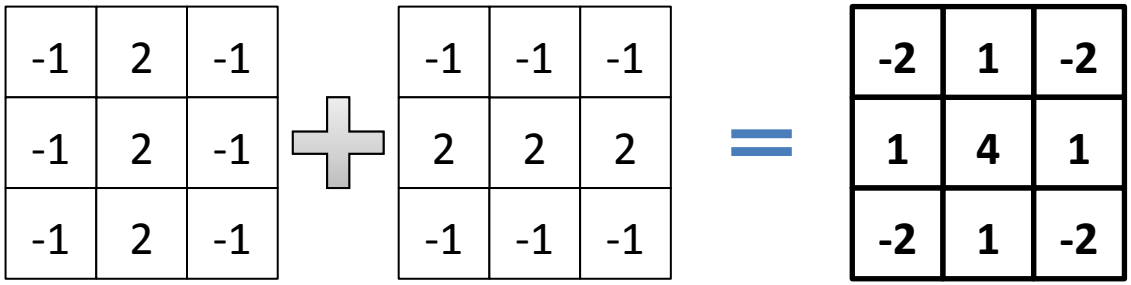
Operatory Laplace’a

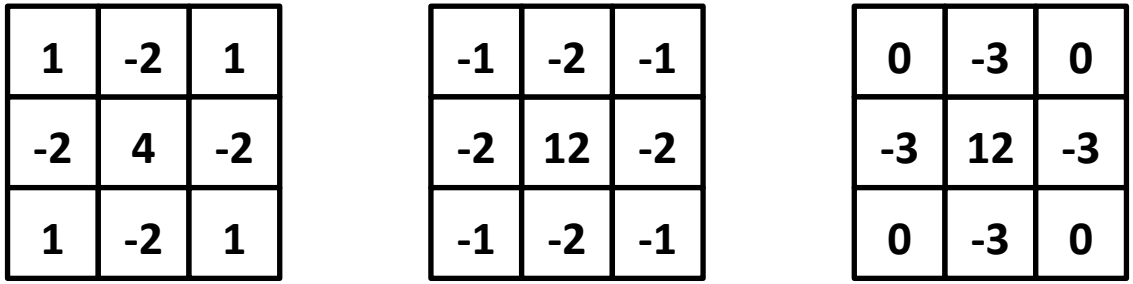




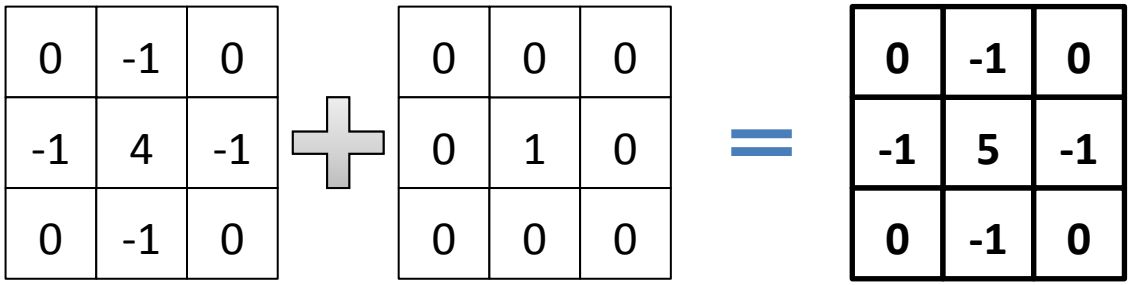
Kierunkowe pochodne cząstkowe

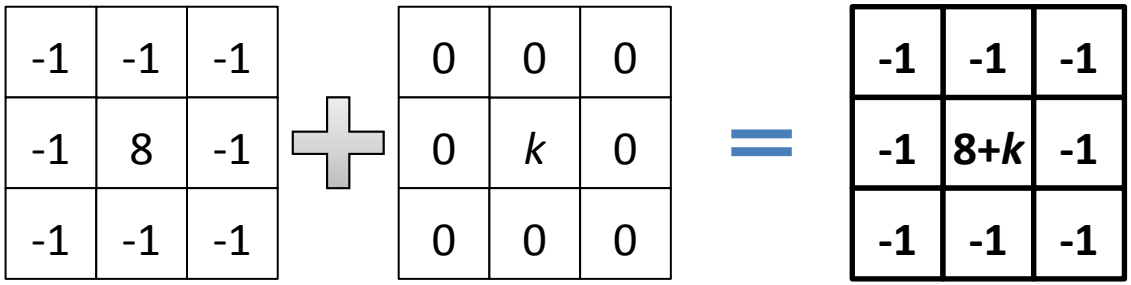
Operatory Laplace’a





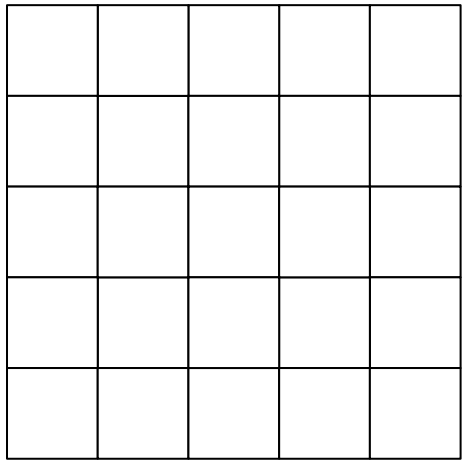
Operatory Laplace'a - wyostrzanie

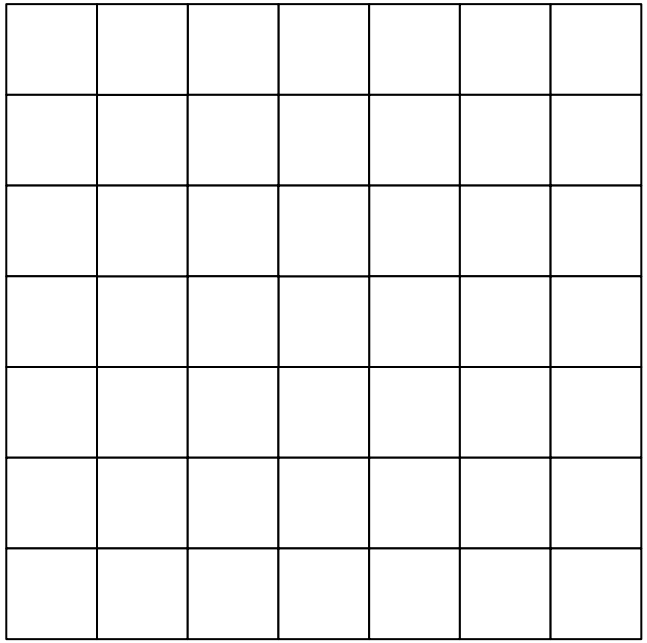


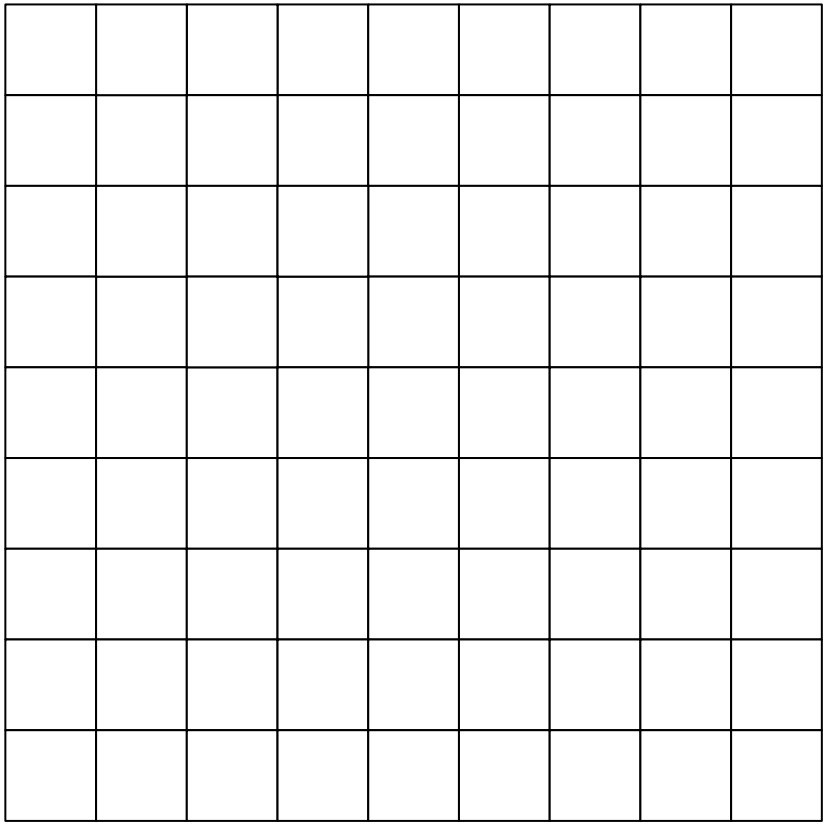


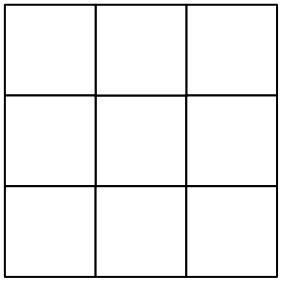
k=1,2,3, …

W TYM MIEJSCU PRZEWIDZIANY JEST POKAZ NA ŻYWO (19.11.2021) …..









Filtr Gaussa

1D

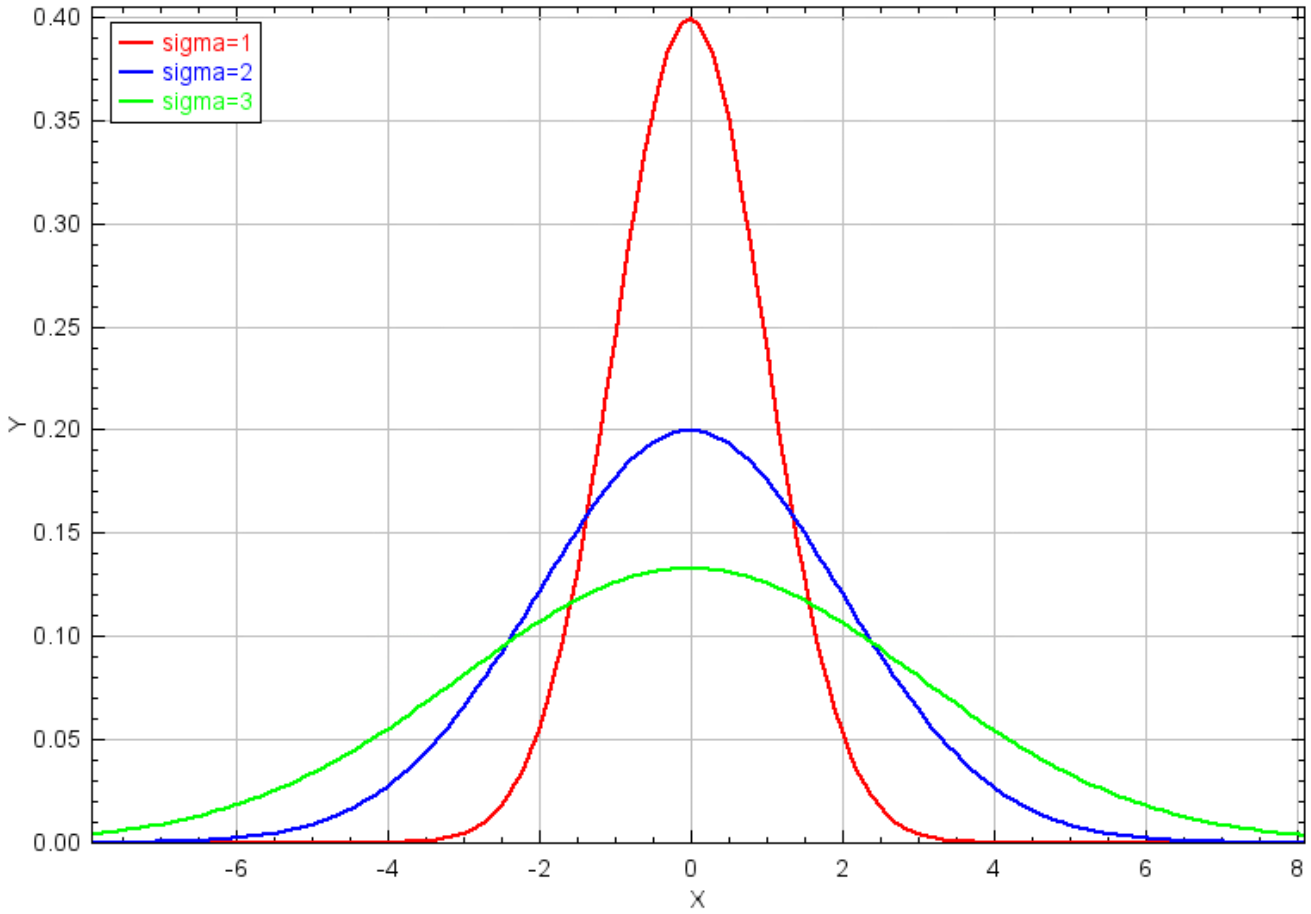
$$G(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{x^2}{2\sigma^2}}$$

```
s = 1.0;

N = 8; // rozmiar

dokladnosc = 0.1;

tab_x = newArray((N*2)/dokladnosc);
tab_y = newArray((N*2)/dokladnosc);

Plot.create("Gauss", "X", "Y");

for(i =-N; i<N+dokladnosc; i+=dokladnosc)
{
          tab_x[(i+N)/dokladnosc] = i;
          tab_y[(i+N)/dokladnosc] =  Gauss1D(i, s);
}

function Gauss(x, y, sigma)
{
          return  (1.0 / (sqrt(2*PI* sigma*sigma))) * exp( -(x*x )/(2.0*sigma*sigma) ) ;
}

Plot.add("line", tab_x, tab_y);
```

Filtr Gaussa

1D

$$G(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{x^2}{2\sigma^2}}$$



Filtr Gaussa

2D

$$G(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{x^2}{2\sigma^2}}$$ 1D

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

```
s = 3.0;

N = 4; // rozmiar 2*N+1, czyli 9

for(i=-N; i<=N; i++)
{
        linia="";

        for(j=-N; j<=N; j++)
                linia+= " " + round( 100* Gauss(i, j, s));
        print(linia);
}


function Gauss(x, y, sigma)
{
        return  (1.0 / (2*PI* sigma*sigma)) * exp( -(x*x + y*y)/(2.0*sigma*sigma) ) ;
}
```

Filtr Gaussa

sigma=1

0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	1	2	1	0	0	0
0	0	1	6	10	6	1	0	0
0	0	2	10	16	10	2	0	0
0	0	1	6	10	6	1	0	0
0	0	0	1	2	1	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0

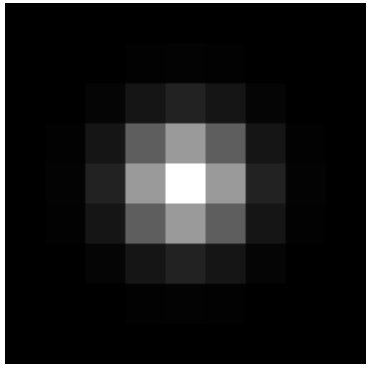
sigma=2

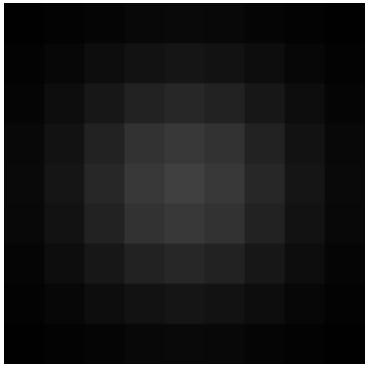
0	0	0	0	1	0	0	0	0
0	0	1	1	1	1	1	0	0
0	1	1	2	2	2	1	1	0
0	1	2	3	4	3	2	1	0
1	1	2	4	4	4	2	1	1
0	1	2	3	4	3	2	1	0
0	1	1	2	2	2	1	1	0
0	0	1	1	1	1	1	0	0
0	0	0	0	1	0	0	0	0

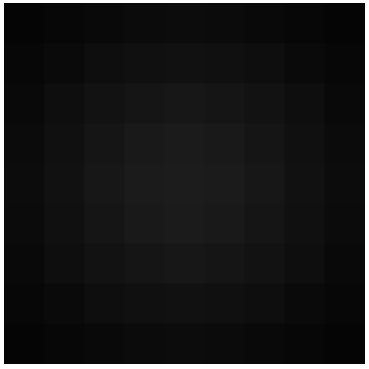
sigma=3

0	0	1	1	1	1	1	0	0
0	1	1	1	1	1	1	1	0
1	1	1	1	1	1	1	1	1
1	1	1	2	2	2	1	1	1
1	1	1	2	2	2	1	1	1
1	1	1	2	2	2	1	1	1
1	1	1	1	1	1	1	1	1
0	1	1	1	1	1	1	1	0
0	0	1	1	1	1	1	0	0

kernel:







Laplacian of Gaussian

Złożenie transformacji 1) Gaussian, 2) Laplacian

$$\mathrm{LoG}(x,y) = -\frac{1}{\pi\sigma^4}\left[1 - \frac{x^2+y^2}{2\sigma^2}\right] e^{-\frac{x^2+y^2}{2\sigma^2}}$$

```
s = 3.0;

N = 4; // rozmiar 2*N+1, czyli 9

for(i=-N; i<=N; i++)
{
          linia="";

          for(j=-N; j<=N; j++)
                    linia+= " " + round( 100* LoG(i, j, s));
          print(linia);
}


function LoG(x, y, sg)
{
   return - (1.0 / (PI* sg*sg*sg*sg)) * (1.0 - (x*x + y*y)/(2.0*sg*sg)) * exp( -(x*x + y*y)/(2.0*sg*sg) ) ;
}
```

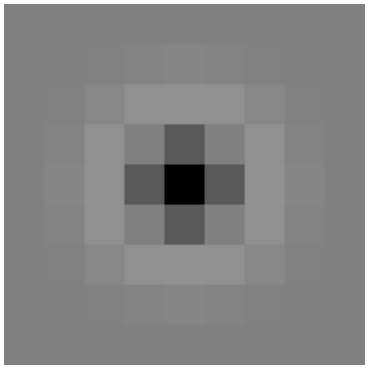
Laplacian of Gaussian

sigma=1.0

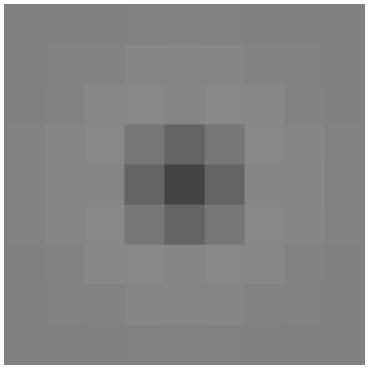
0	0	0	0	0	0	0	0	0
0	0	0	1	1	1	0	0	0
0	0	2	4	4	4	2	0	0
0	1	4	0	-10	0	4	1	0
0	1	4	-10	-32	-10	4	1	0
0	1	4	0	-10	0	4	1	0
0	0	2	4	4	4	2	0	0
0	0	0	1	1	1	0	0	0
0	0	0	0	0	0	0	0	0

sigma=1.2

0	0	0	0	0	0	0	0	0
0	0	1	1	1	1	1	0	0
0	1	2	2	1	2	2	1	0
0	1	2	-2	-7	-2	2	1	0
0	1	1	-7	**-15**	-7	1	1	0
0	1	2	-2	-7	-2	2	1	0
0	1	2	2	1	2	2	1	0
0	0	1	1	1	1	1	0	0
0	0	0	0	0	0	0	0	0



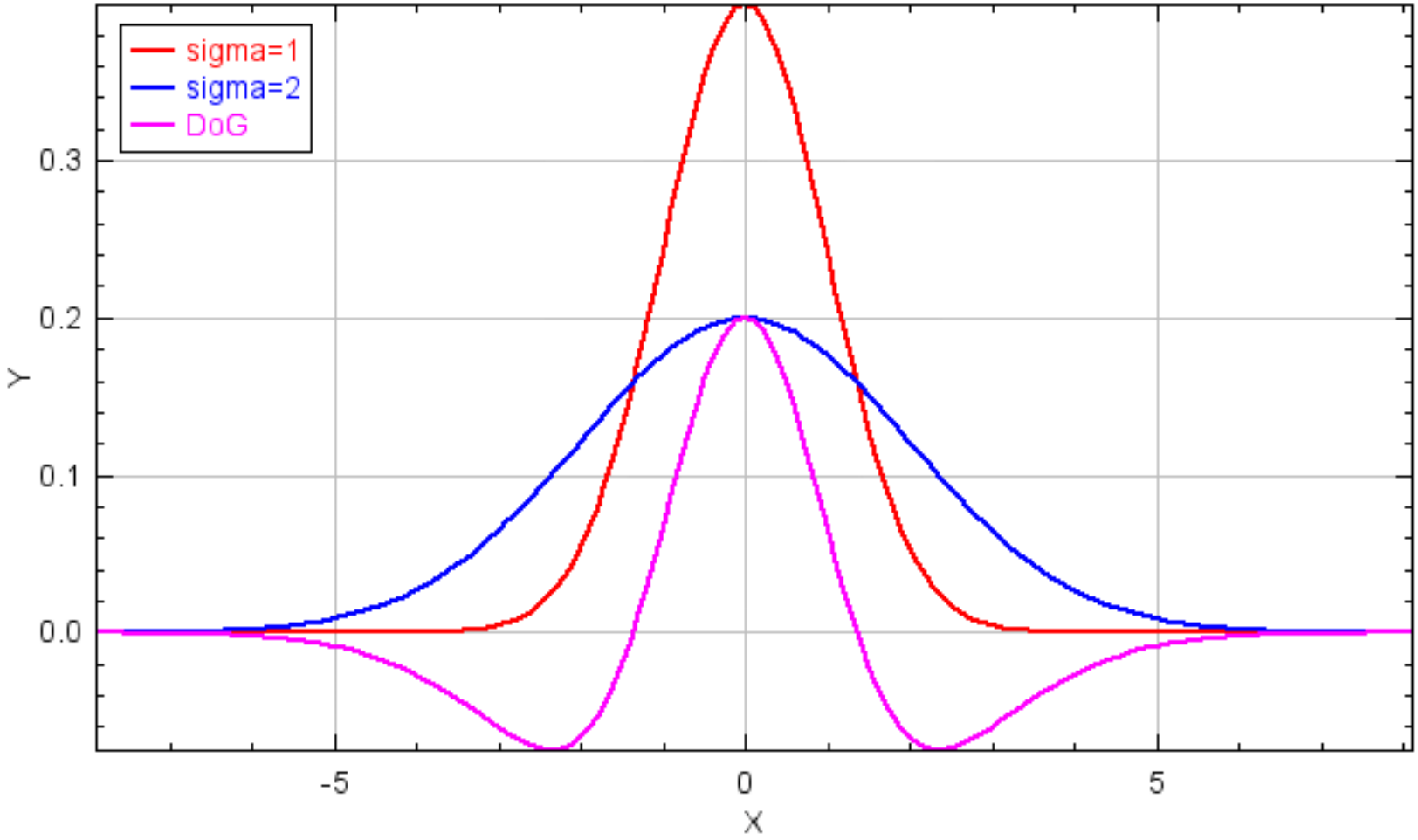
obrazy przesunięte +128



BLOB DETECTION

Mexican Hat

Difference of Gaussian



Difference of Gaussian

sigma=1

0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	1	2	1	0	0	0
0	0	1	6	10	6	1	0	0
0	0	2	10	16	10	2	0	0
0	0	1	6	10	6	1	0	0
0	0	0	1	2	1	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0

sigma=2

0	0	0	0	1	0	0	0	0
0	0	1	1	1	1	1	0	0
0	1	1	2	2	2	1	1	0
0	1	2	3	4	3	2	1	0
1	1	2	4	4	4	2	1	1
0	1	2	3	4	3	2	1	0
0	1	1	2	2	2	1	1	0
0	0	1	1	1	1	1	0	0
0	0	0	0	1	0	0	0	0

sigma=3

0	0	1	1	1	1	1	0	0
0	1	1	1	1	1	1	1	0
1	1	1	1	1	1	1	1	1
1	1	1	2	2	2	1	1	1
1	1	1	2	2	2	1	1	1
1	1	1	2	2	2	1	1	1
1	1	1	1	1	1	1	1	1
0	1	1	1	1	1	1	1	0
0	0	1	1	1	1	1	0	0

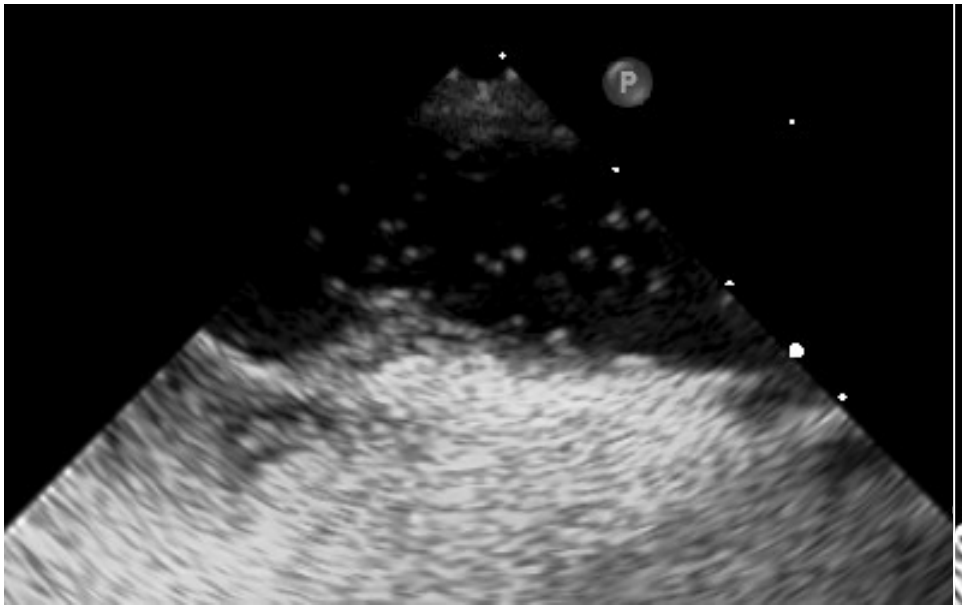
sigma=1 - sigma=2

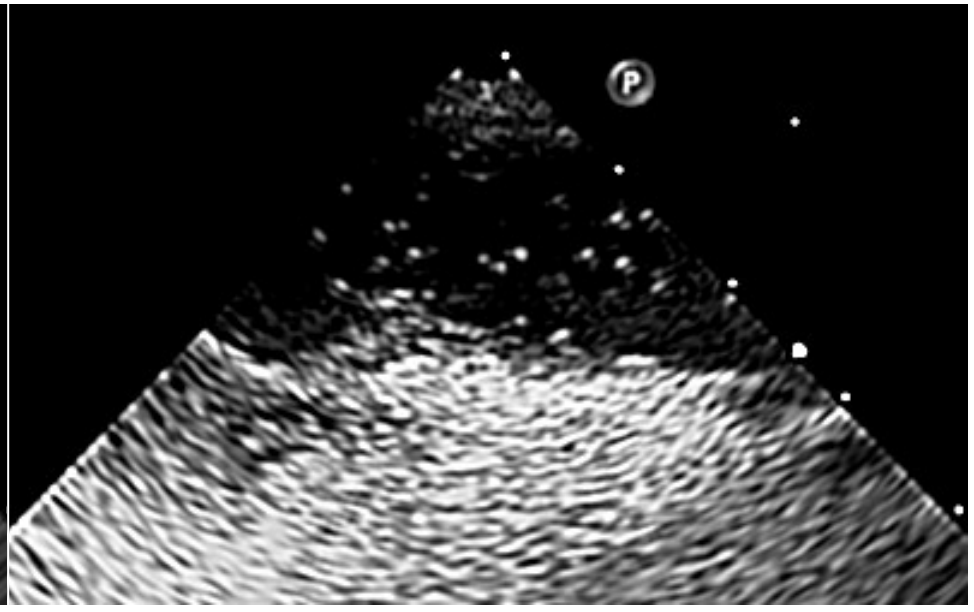
0	0	0	0	-1	0	0	0	0
0	0	-1	-1	-1	-1	-1	0	0
0	-1	-1	-1	0	-1	-1	-1	0
0	-1	-1	3	6	3	-1	-1	0
-1	-1	0	6	12	6	0	-1	-1
0	-1	-1	3	6	3	-1	-1	0
0	-1	-1	-1	0	-1	-1	-1	0
0	0	-1	-1	-1	-1	-1	0	0
0	0	0	0	-1	0	0	0	0

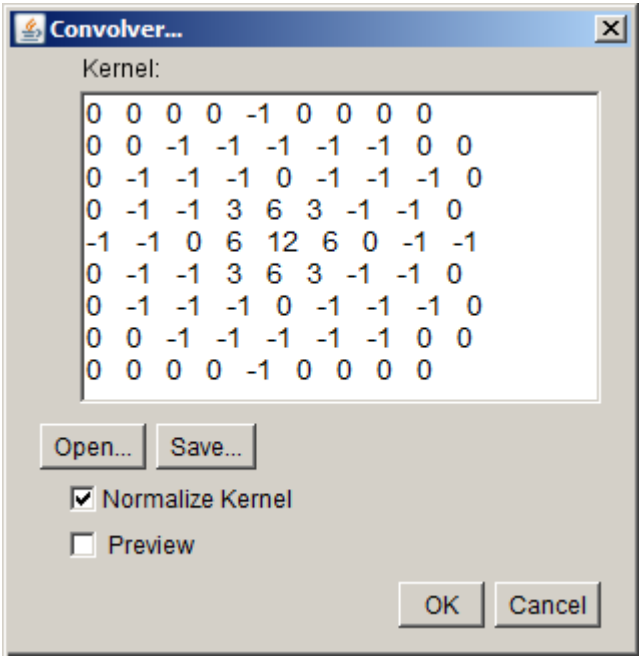
sigma=1 - sigma=3

0	0	-1	-1	-1	-1	-1	0	0
0	-1	-1	-1	-1	-1	-1	-1	0
-1	-1	-1	0	1	0	-1	-1	-1
-1	-1	0	4	8	4	0	-1	-1
-1	-1	1	8	14	8	1	-1	-1
-1	-1	0	4	8	4	0	-1	-1
-1	-1	-1	0	1	0	-1	-1	-1
0	-1	-1	-1	-1	-1	-1	-1	0
0	0	-1	-1	-1	-1	-1	0	0

Difference of Gaussian

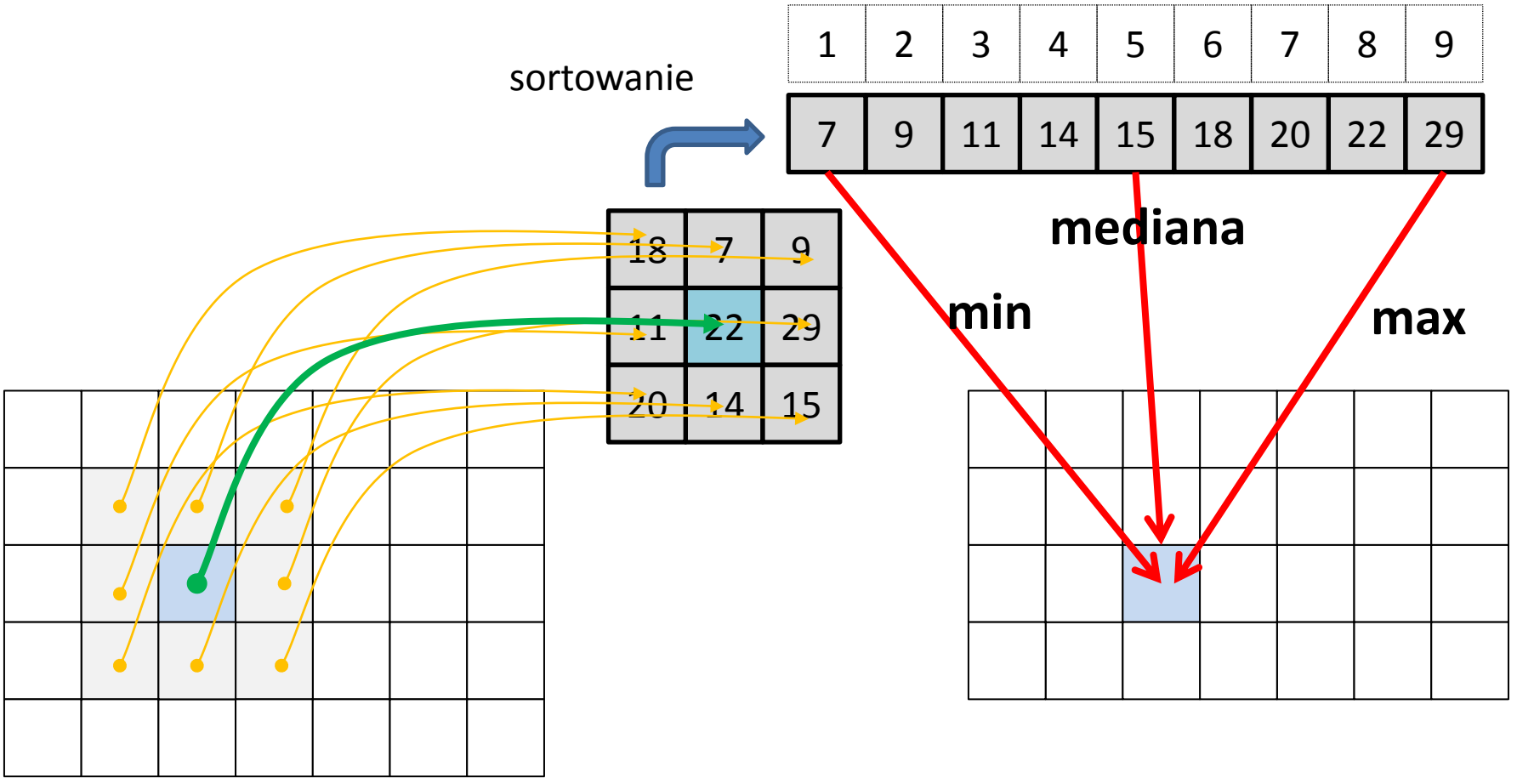






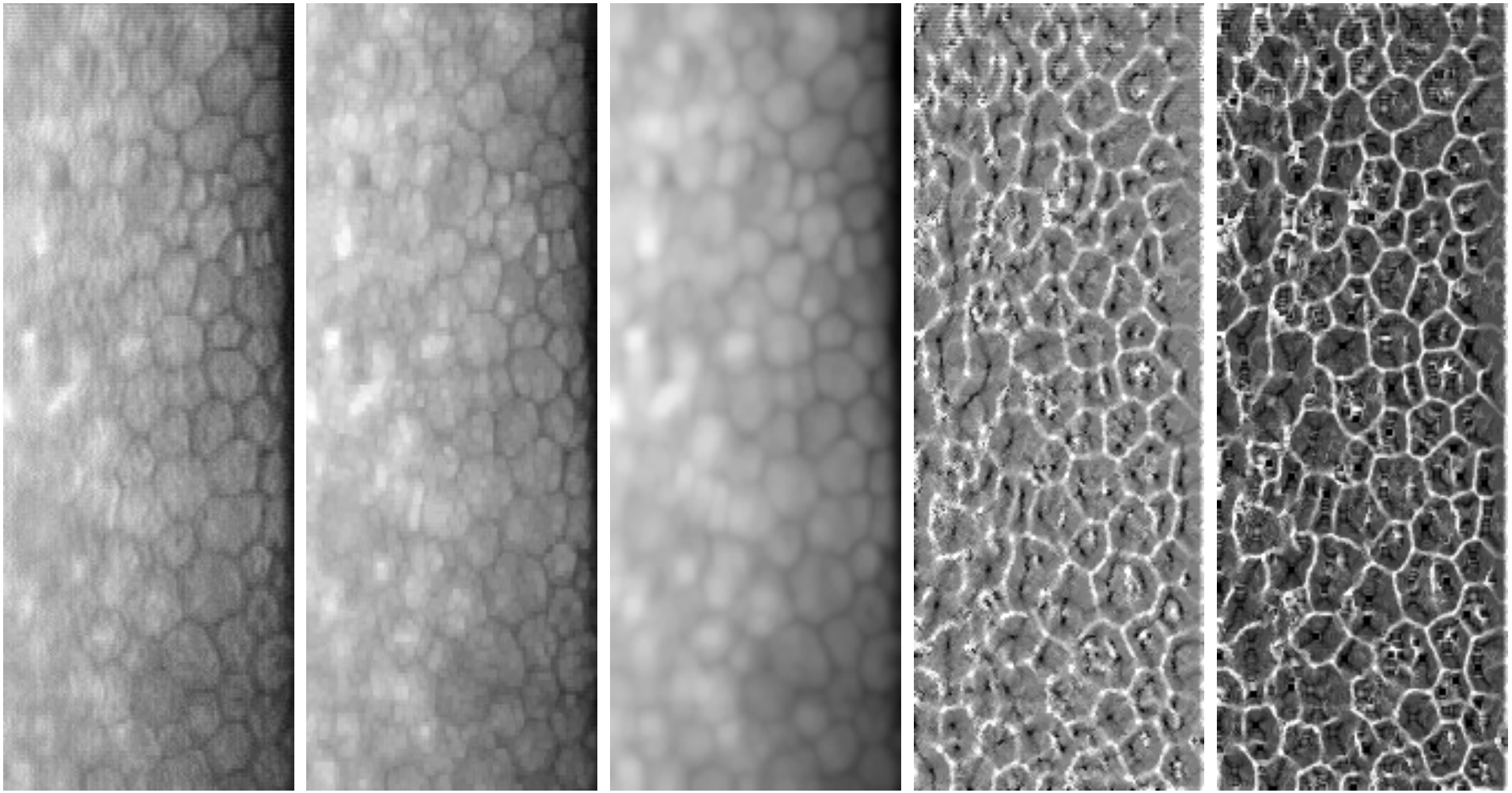
Sorysz, J., Sorysz, D., Piórkowski, A.: Segmentation of a First Generation Agent Bubbles in the B-Mode Echocardiographic Images. IEEE EMBS ICS 2020. Springer 2022, AISC, vol 1360, pp. 127-135

Filtry rankingowe



- nie wprowadzają nowych wartości poziomów jasności
- mediana w dużym stopniu pozostawia definicje krawędzi

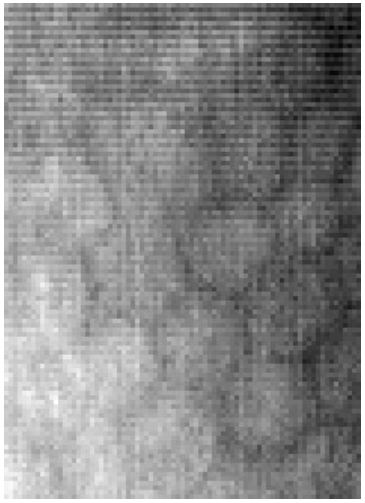
Filtr maksymalny – przykład wykorzystania



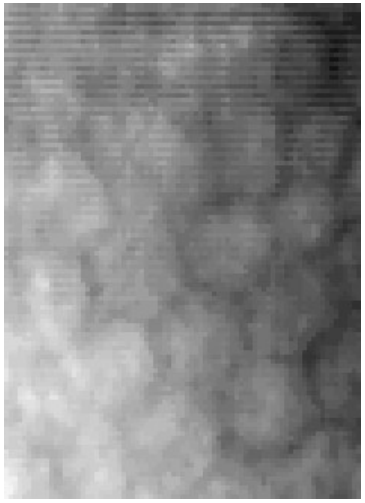
org | **max** [3x3] | mean r=3.5 **max** [3x3] | mean r=3.5 SDAr3 | mean r=3.5 **max** [3x3] SDAr3

Piorkowski A.: A Statistical Dominance Algorithm for Edge Detection and Segmentation of Medical Images. AISC vol. 471, Springer 2016, pp. 3-14.

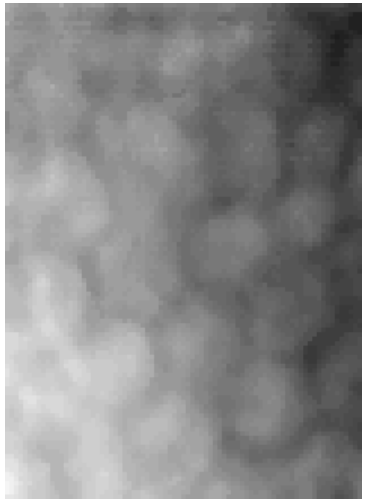
Mediana a uśrednianie



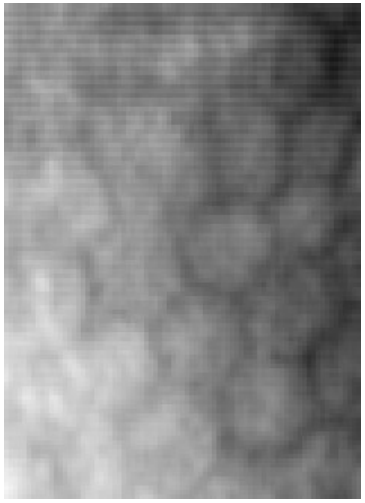
obraz źródłowy



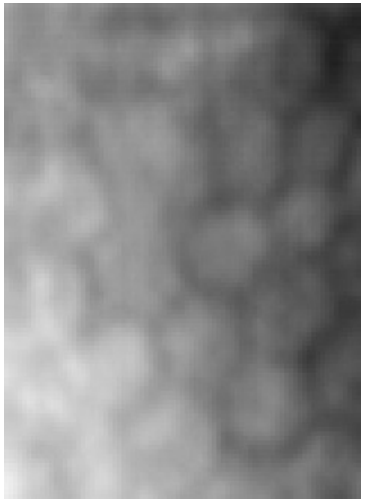
mediana r=1



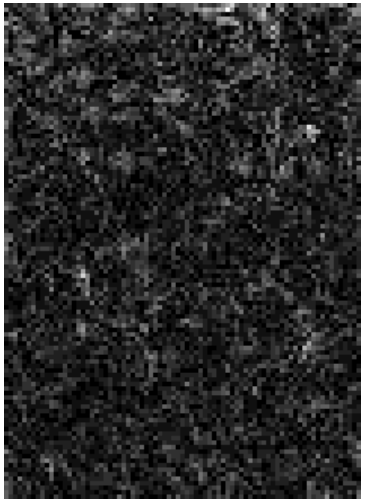
mediana r=2

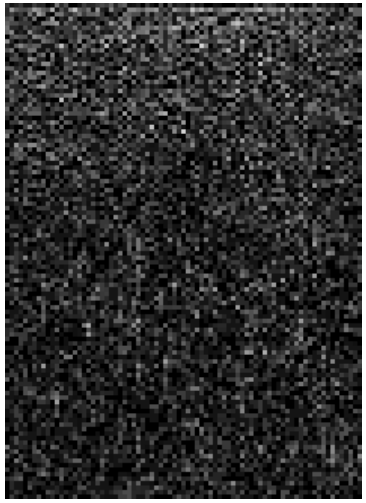


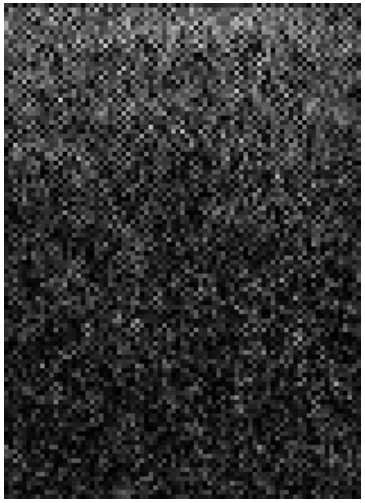
średnia r=1

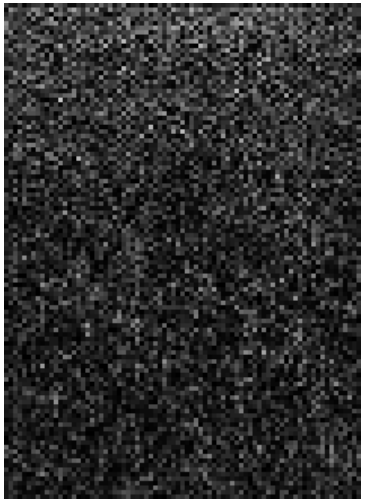


średnia r=2





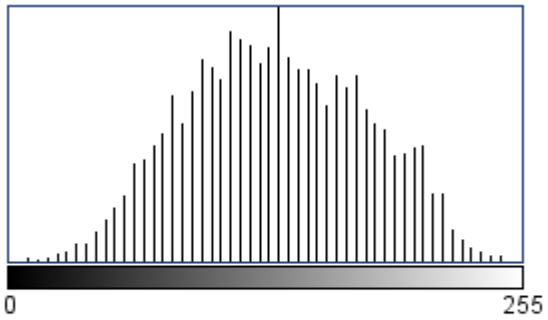




Różnica między medianą r=2
a średnią r=2, pomnożona 8x

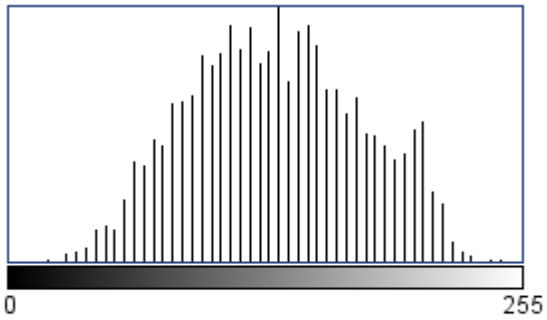
Różnica w stosunku do obrazu źródłowego, pomnożona x4

Mediana a uśrednianie



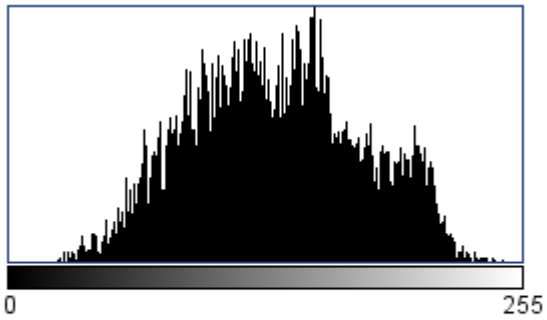
N: 8690 Min: 0
Mean: 132.410 Max: 255
StdDev: 45.093 Mode: 134 (390)
Value: 232 Count: 0

obraz źródłowy



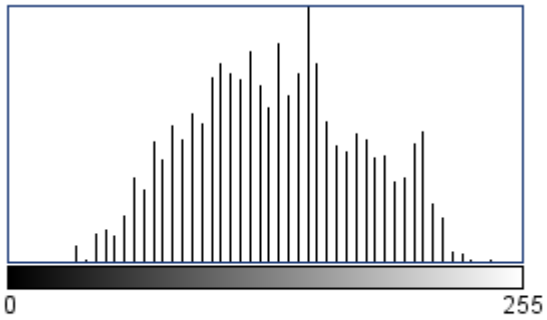
N: 8690 Min: 19
Mean: 132.444 Max: 245
StdDev: 43.139 Mode: 134 (393)
Value: 13 Count: 0

mediana r=1



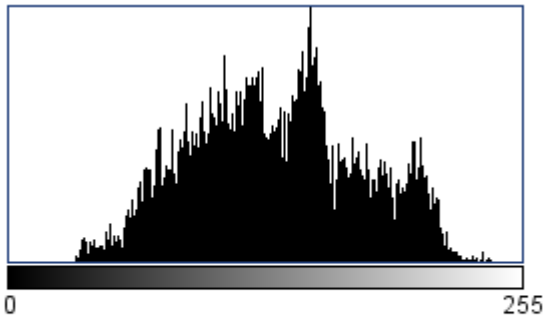
N: 8690 Min: 24
Mean: 132.412 Max: 246
StdDev: 42.930 Mode: 152 (94)

średnia r=1



N: 8690 Min: 28
Mean: 132.548 Max: 245
StdDev: 42.486 Mode: 149 (464)
Value: 9 Count: 0

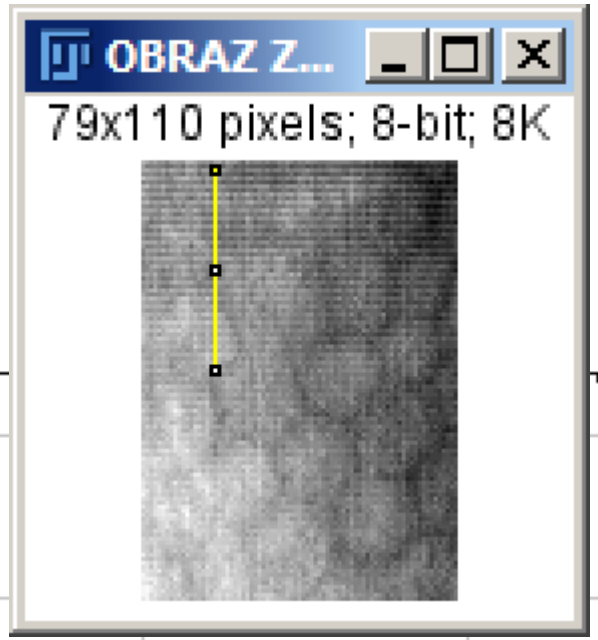
mediana r=2

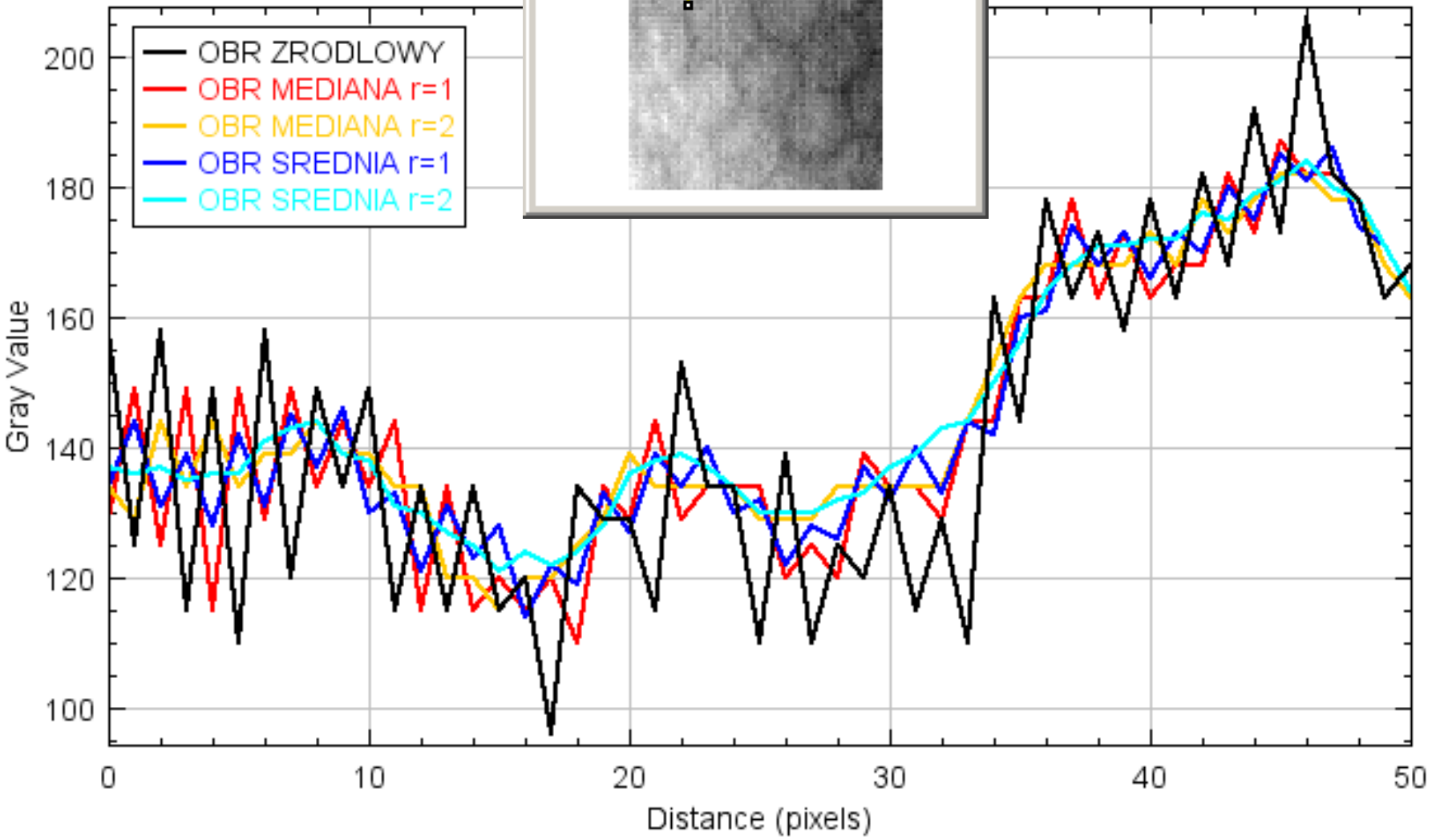


N: 8690 Min: 33
Mean: 132.461 Max: 240
StdDev: 42.432 Mode: 150 (114)
Value: --- Count: ---

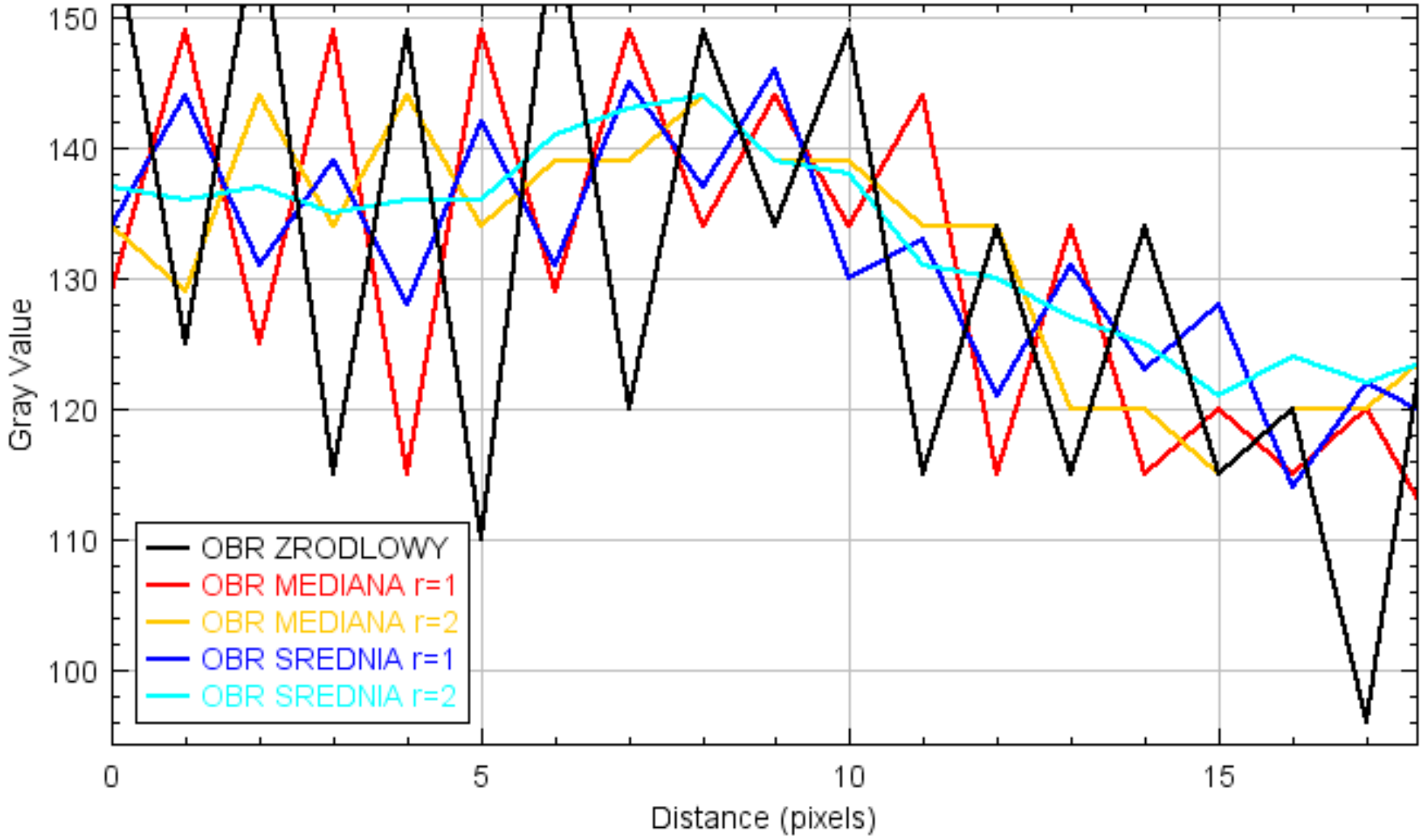
średnia r=2

Mediana a uśrednianie

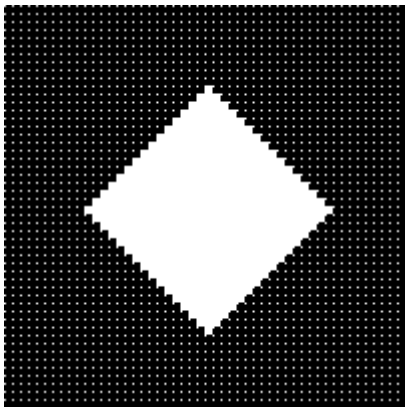


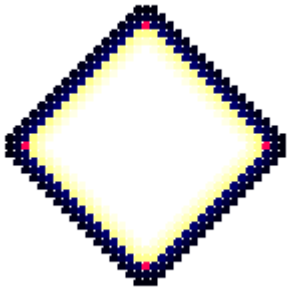


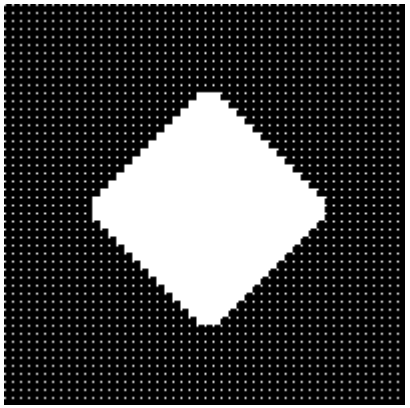
Mediana a uśrednianie



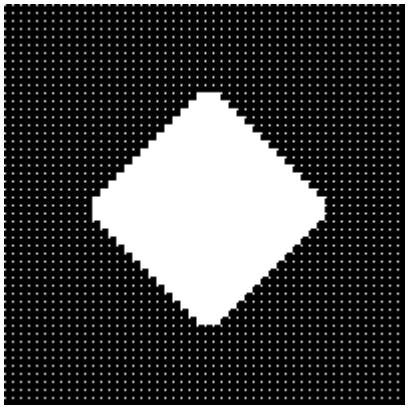
Mediana a uśrednianie



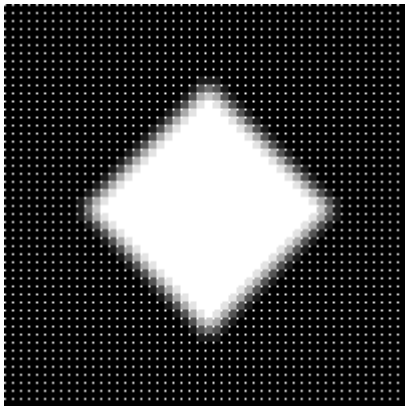




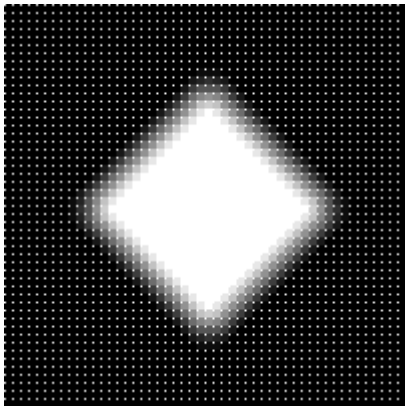
mediana r=1



mediana r=2

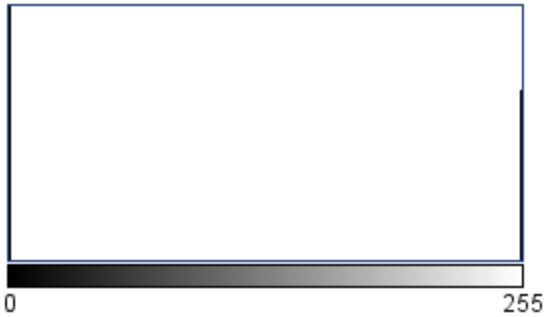


średnia r=1



średnia r=2

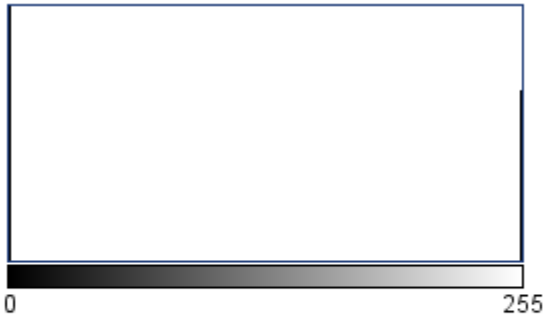
Mediana a uśrednianie



N: 2500
Mean: 49.062
StdDev: 100.537
Value: 189

Min: 0
Max: 255
Mode: 0 (2019)
Count: 0

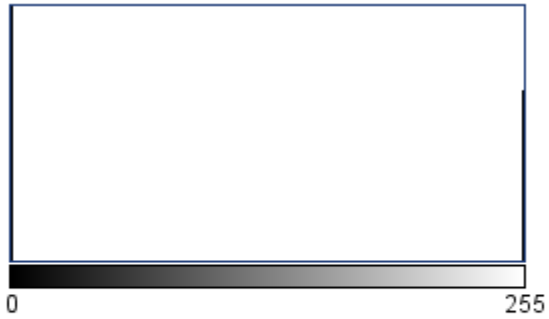
mediana r=1



N: 2500
Mean: 48.654
StdDev: 100.218
Value: 254

Min: 0
Max: 255
Mode: 0 (2023)
Count: 0

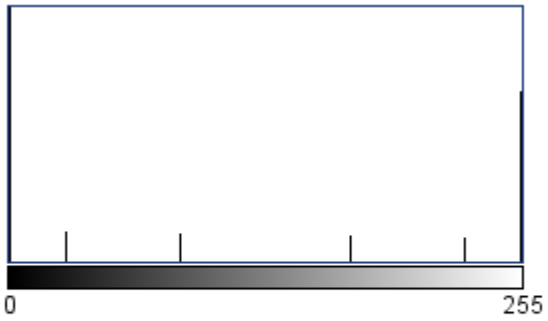
mediana r=2



N: 2500
Mean: 48.654
StdDev: 100.218
Value: 241

Min: 0
Max: 255
Mode: 0 (2023)
Count: 0

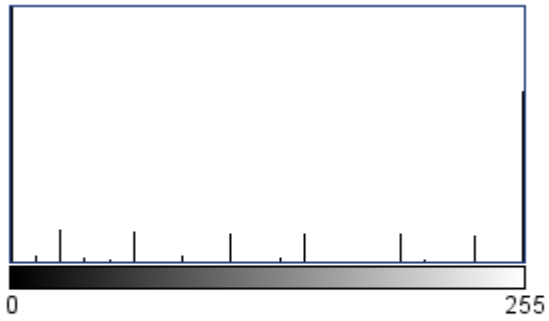
średnia r=1



N: 2500
Mean: 49.059
StdDev: 95.329

Min: 0
Max: 255
Mode: 0 (1891)

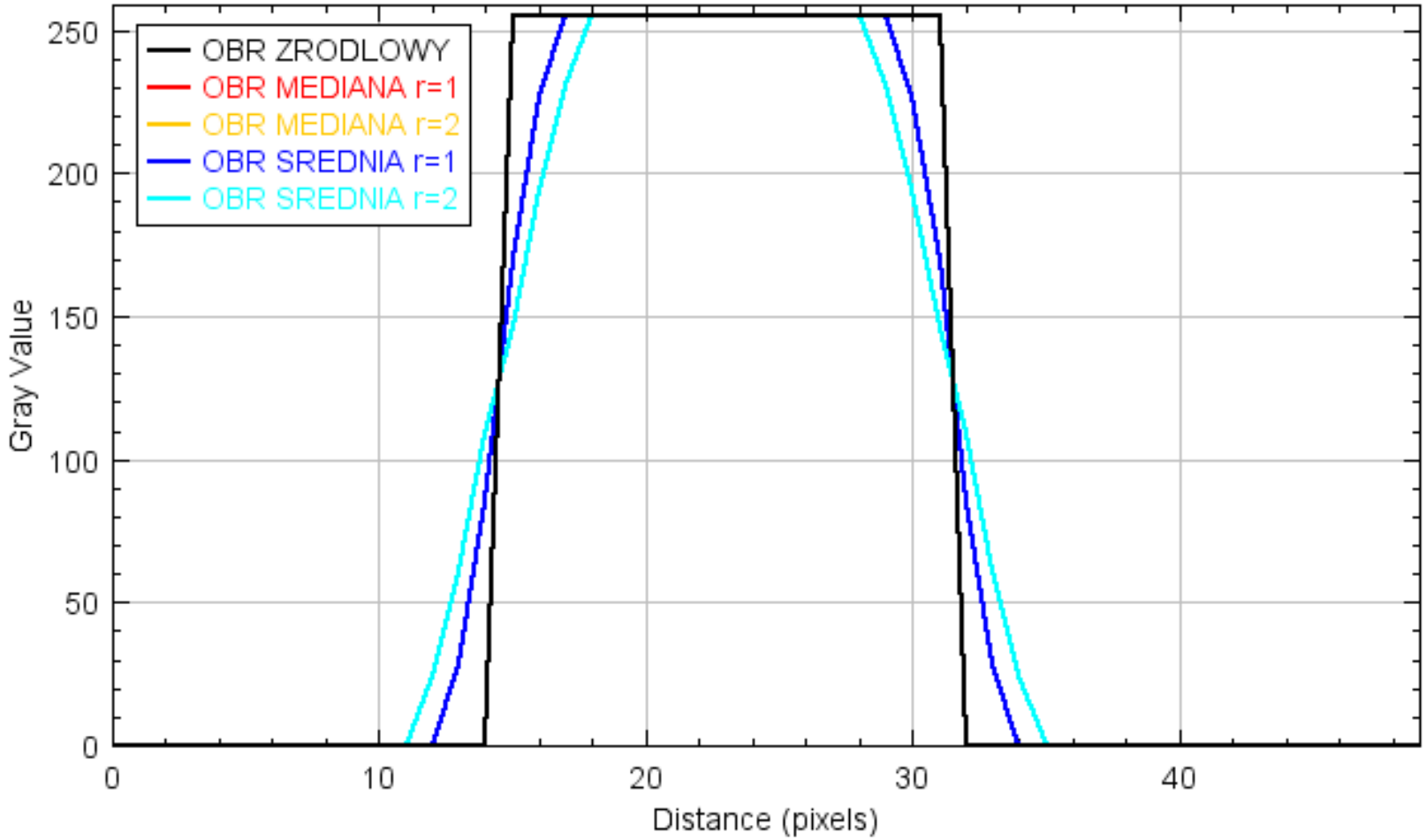
średnia r=2

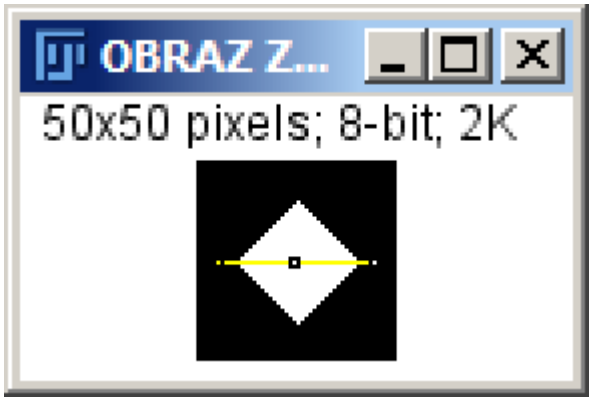


N: 2500
Mean: 49.060
StdDev: 92.203
Value: 150

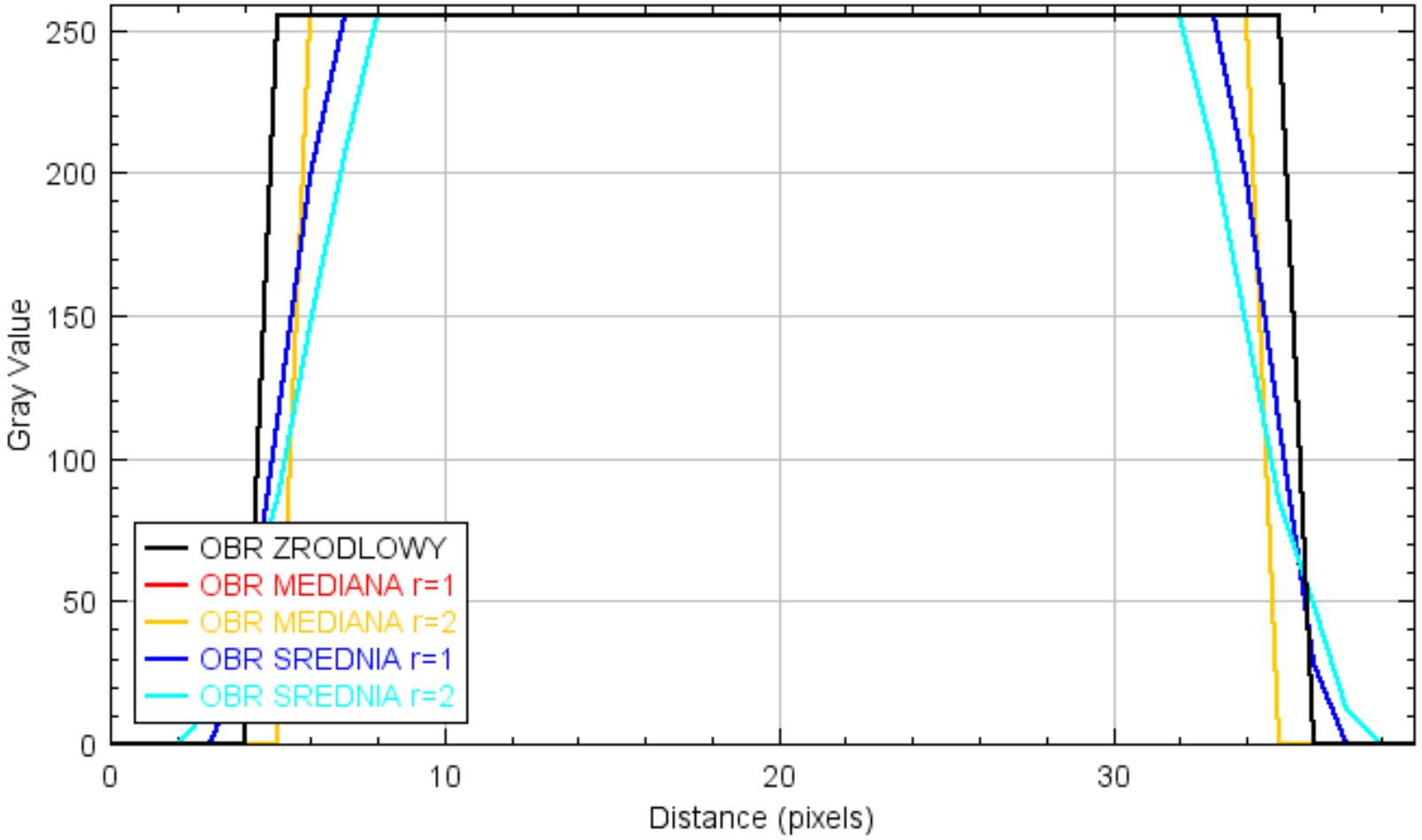
Min: 0
Max: 255
Mode: 0 (1819)
Count: 0

Mediana a uśrednianie

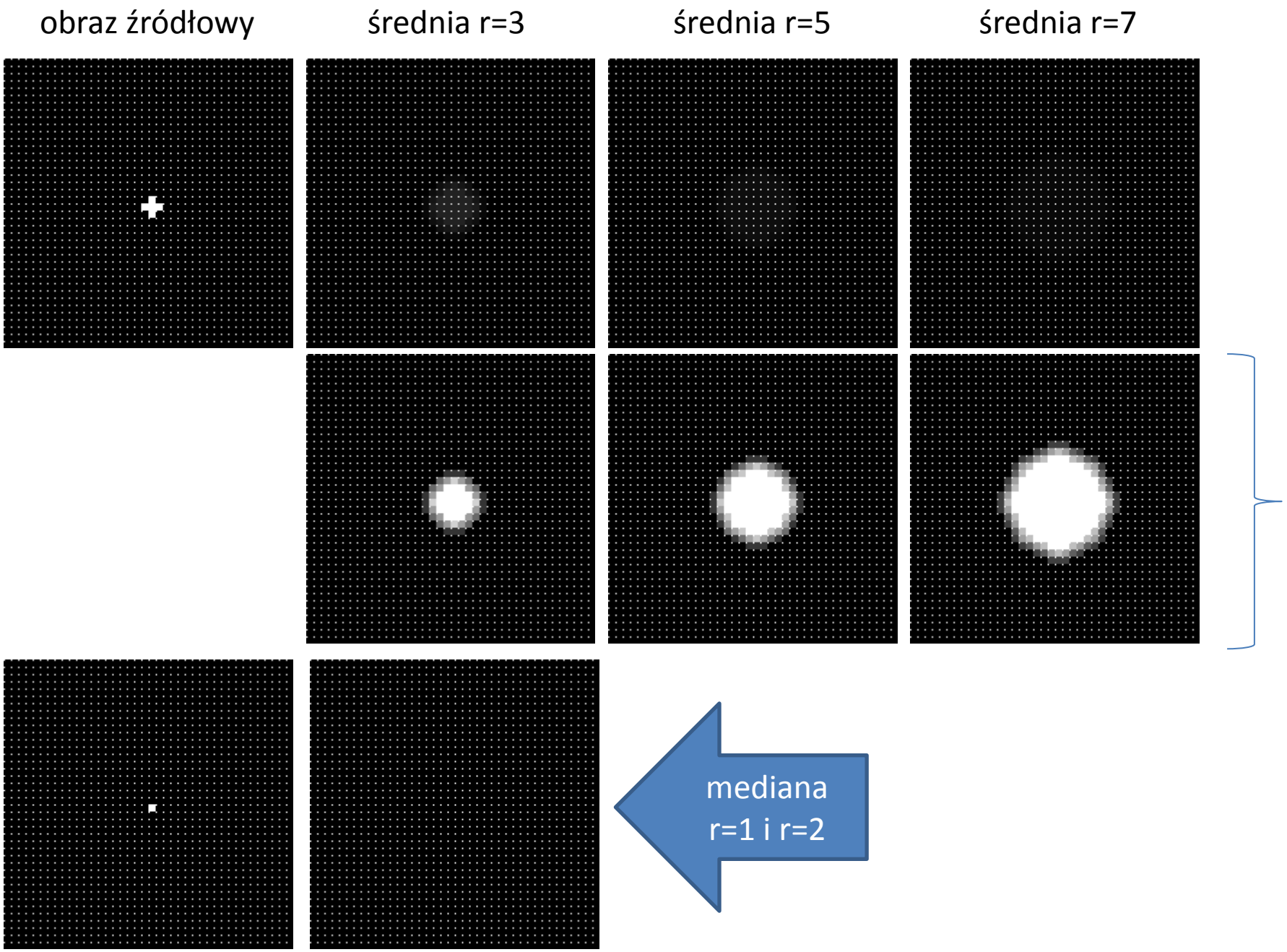




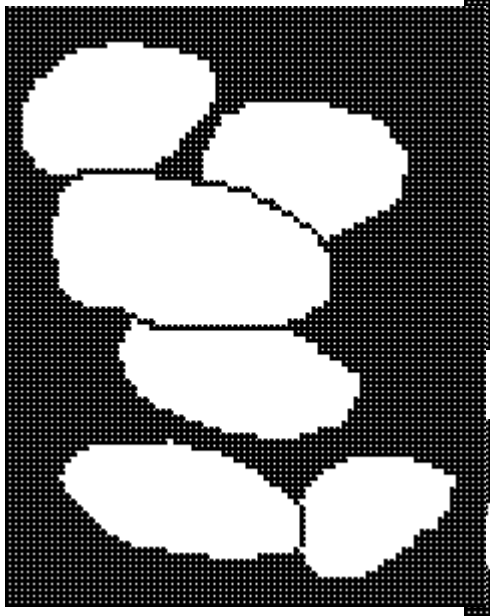
Mediana a uśrednianie

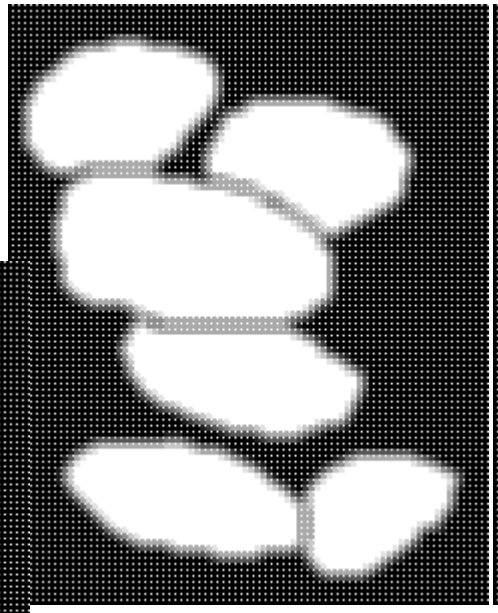


Mediana a uśrednianie - sąsiedztwo

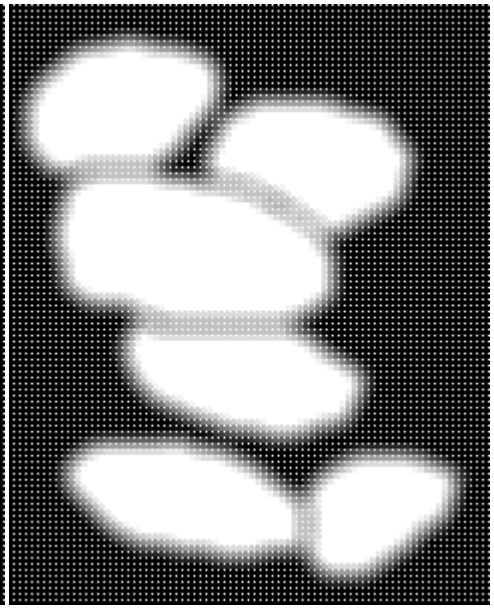


Mediana a uśrednianie - sąsiedztwo

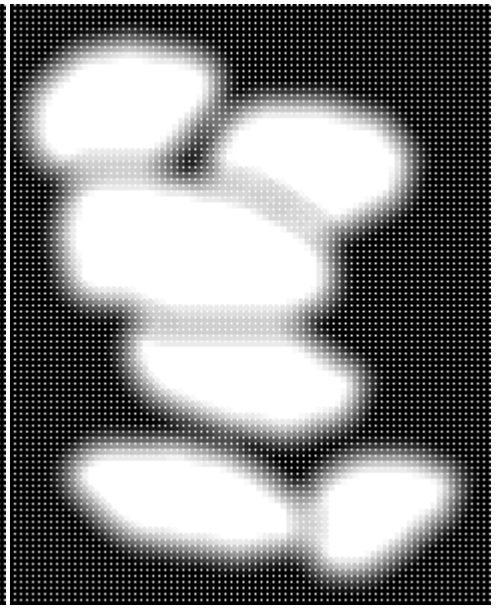




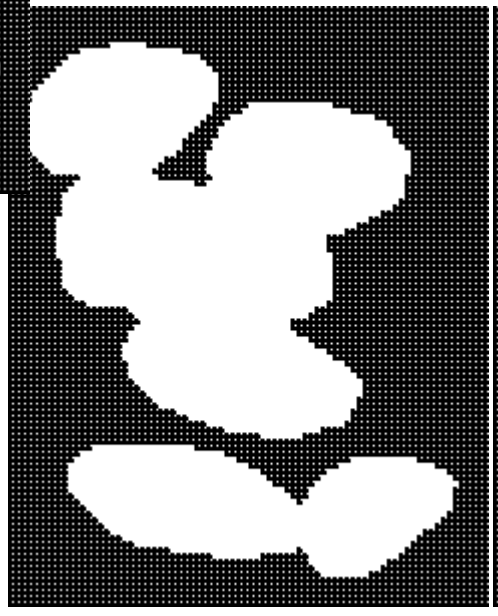
r=1

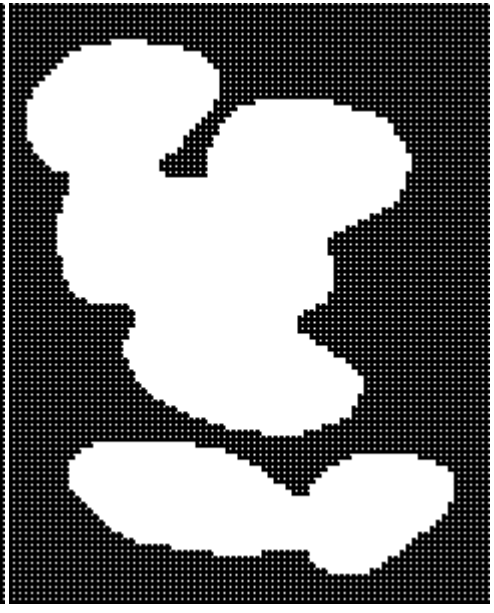


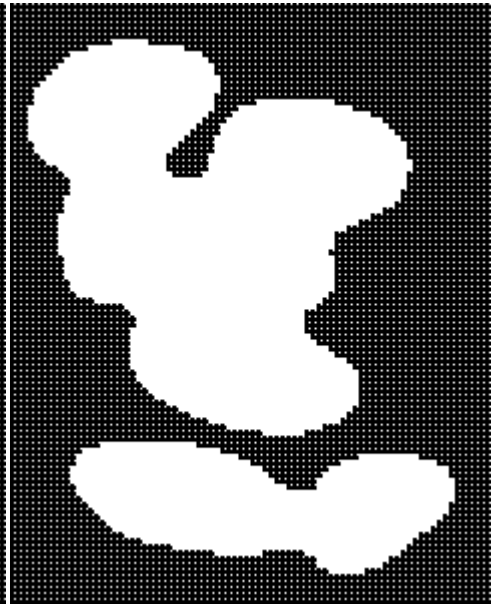
r=2



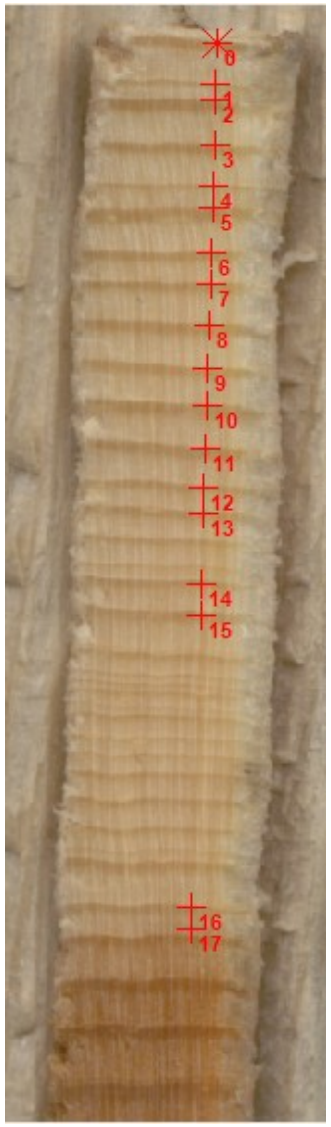
r=3





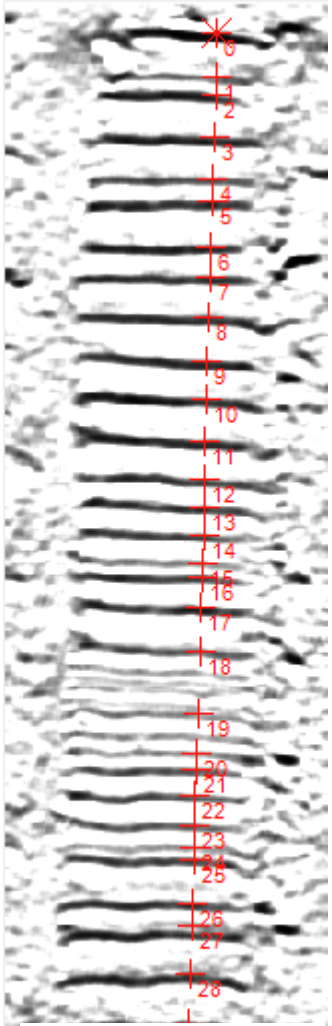


Filtracja kierunkowa

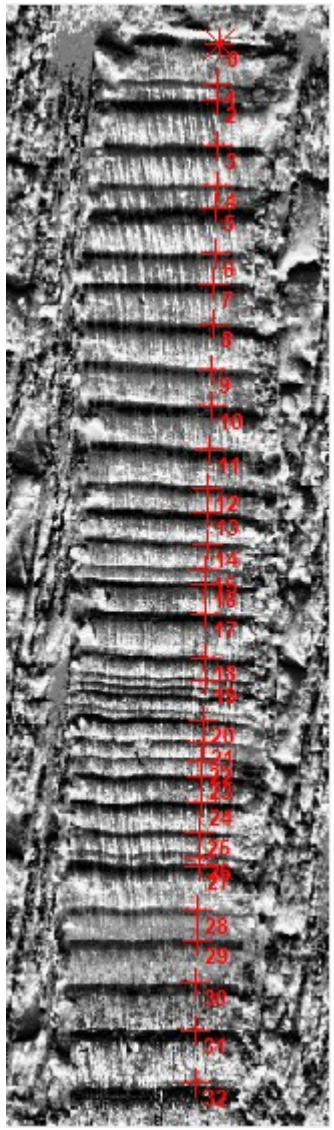


program X

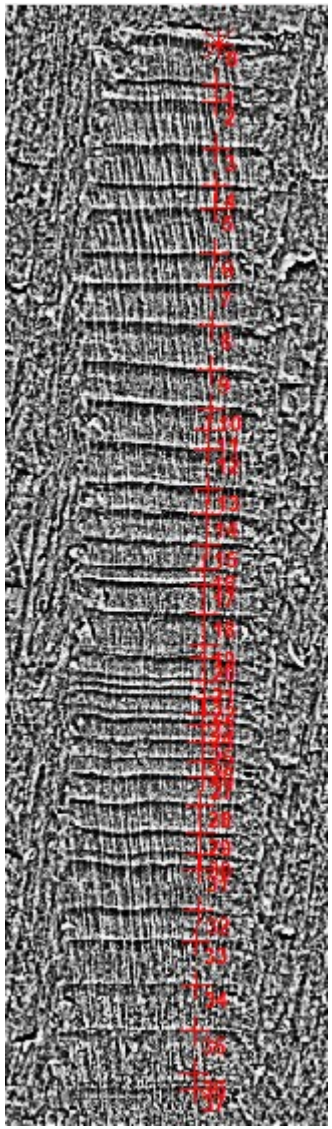
ręcznie



$$\begin{bmatrix} 3 & 3 & 3 & 3 & 3 & 3 & 3 \\ 2 & 2 & 2 & 2 & 2 & 2 & 2 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & -1 & -1 & -1 & -1 & -1 & -1 \\ -2 & -2 & -2 & -2 & -2 & -2 & -2 \\ -3 & -3 & -3 & -3 & -3 & -3 & -3 \end{bmatrix}$$



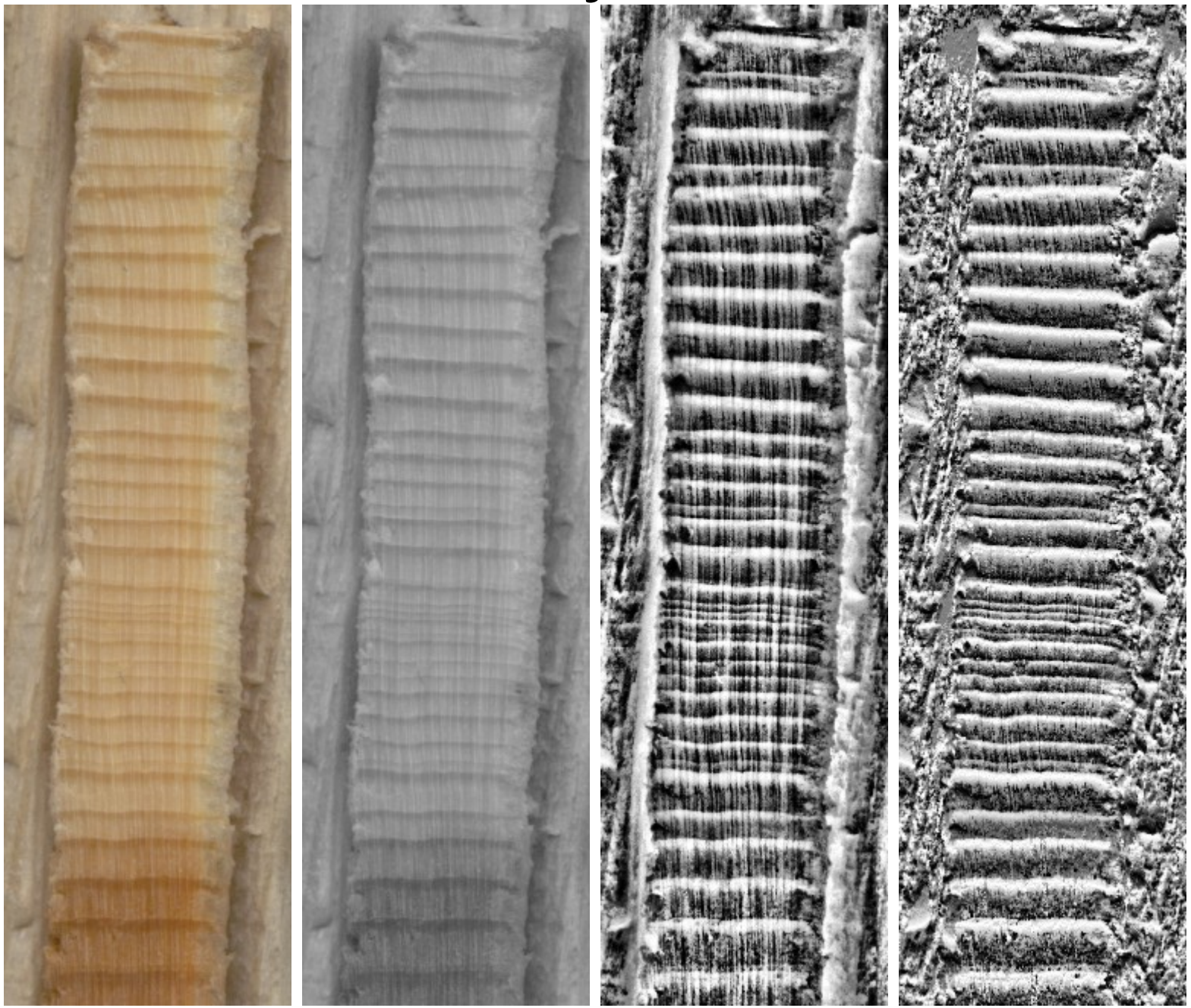
SDA, r=30H



norm r=30
SDA, r=30H

Fabijańska A., Danek M., Barniak J., Piórkowski A.: A Comparative Study of Image -Ring Analysis. IP&C 2016. Springer, 2017, AISC, vol 525, pp 69-78

Filtracja kierunkowa



(3)
dla maski
koło,
r=20

(4)
dla maski
pionowej,
r=20

Filtry oszczędzające krawędzie

- Sigma Filter
- Non-Local Means
- Kuwahara
- Bilateral Filter
- Anisotropic Diffusion
- …

Lokalne wyrównywanie histogramu

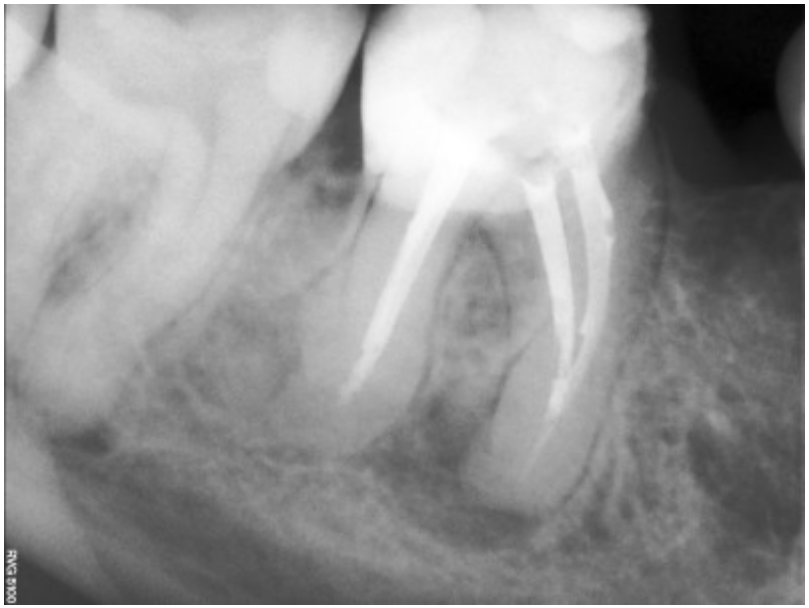
- wykonywane w zadanym sąsiedztwie (punkt centralny histogramu),
- AHE – Adaptive Histogram Equalization
- CLAHE – Contrast Limited AHE

- jest parametryczne (zależy od rozmiaru regionu)
- zwiększa kontrast krawędzi
- zwiększa udział szumu …

Autorska kombinacja ☺

src

HIST EQ



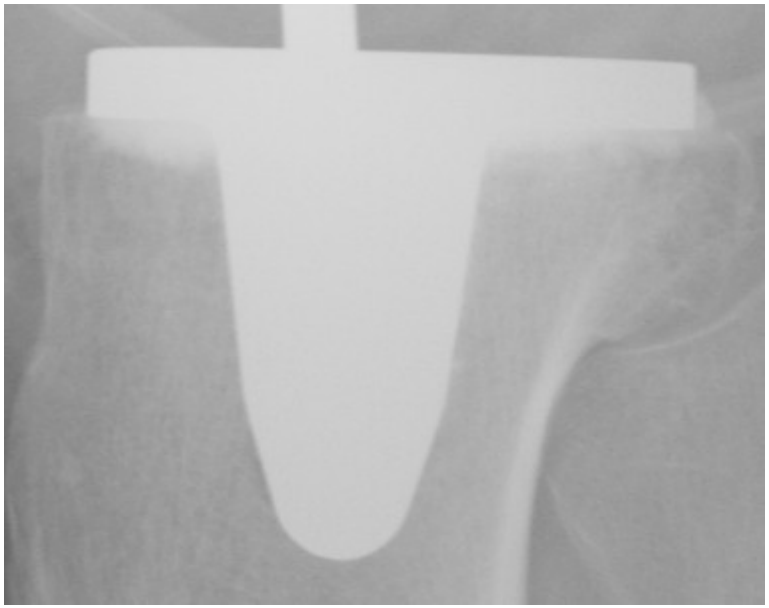
CLAHE

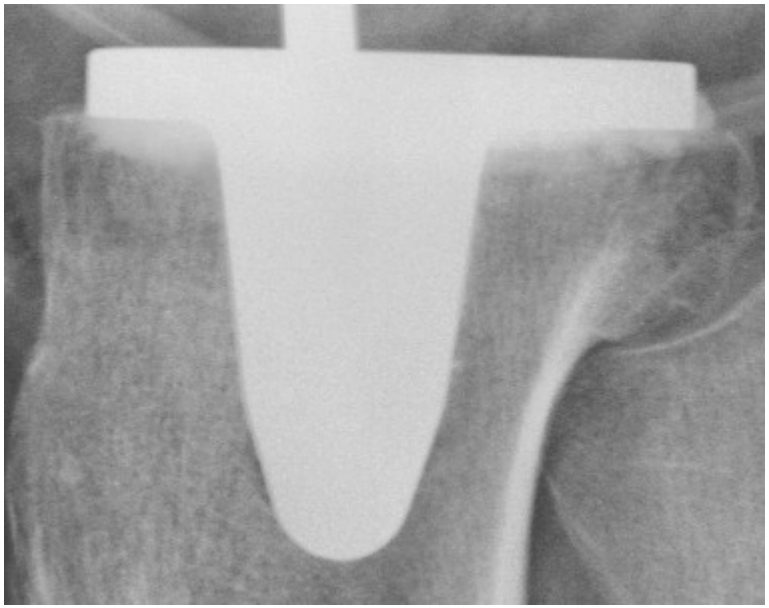
CLAHE -> HISTEQ

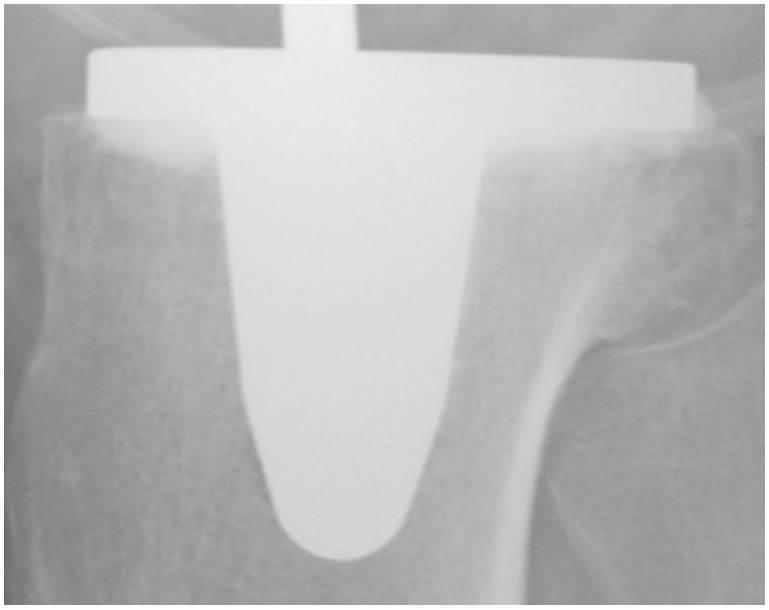
Łebska J., Obuchowicz B., Obuchowicz R., Piórkowski A.: Comparison of the Effects of Different Preprocessing Methods on Homogeneity Assessment of Digital Intraoral Radiographs of Root Canal Fillings. IP&C 2021. Springer, 2022, LNNS, vol 255, pp 145-152

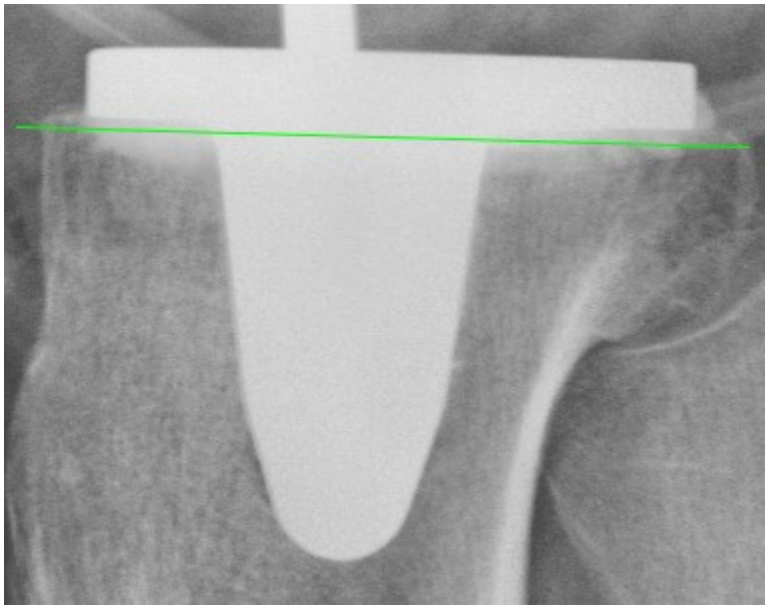
SRC

CLAHE



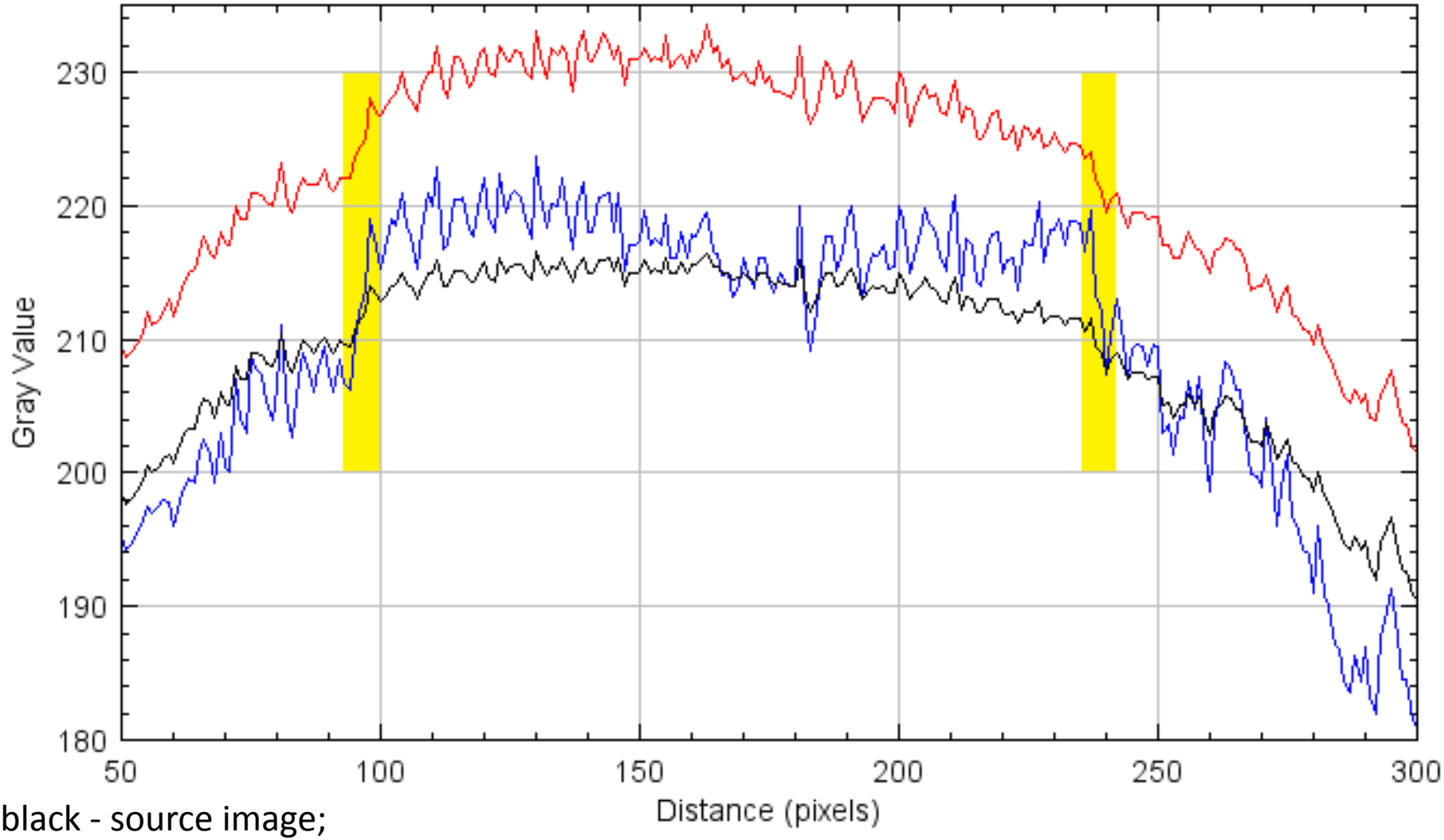






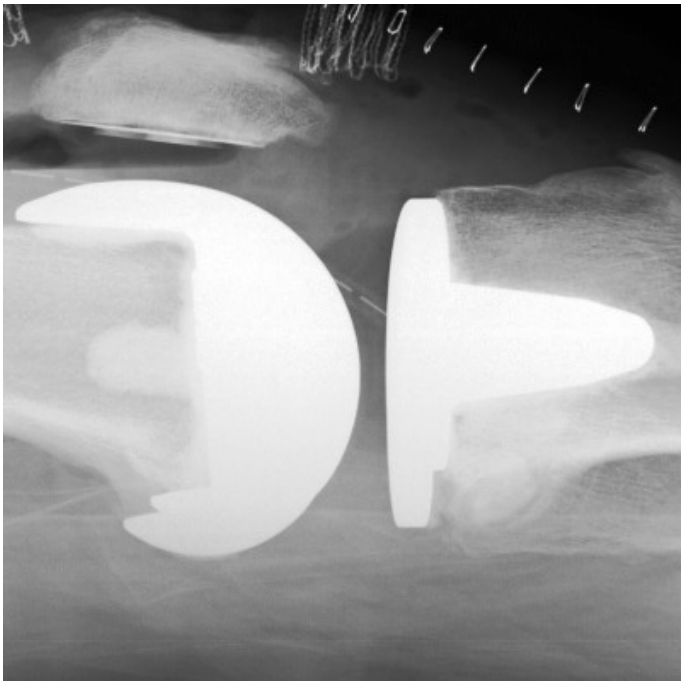
HIST EQ

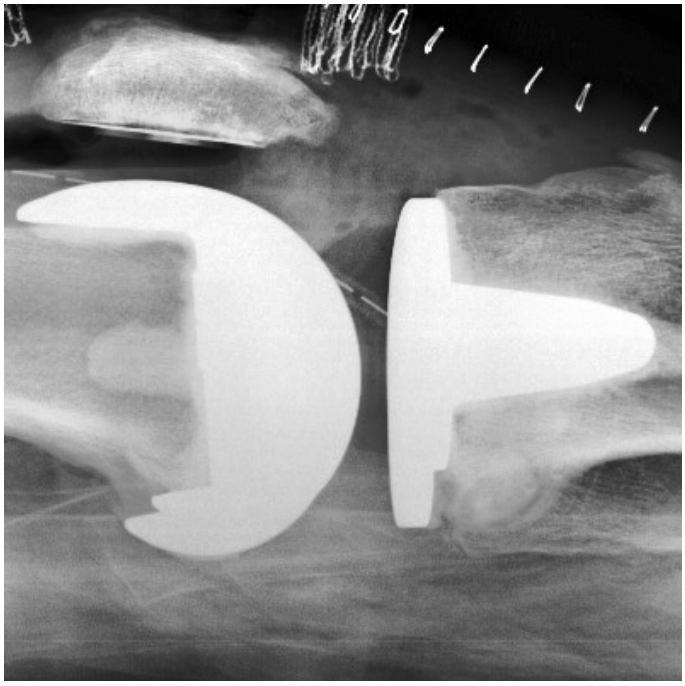
Uwaga! Powyższe obrazy są jedynie fragmentami pełnego radiogramu



black - source image;
red - after histogram equalization;
blue - after CLAHE;
yellow zone - the signal slope on the edges of the implant.

Smolikowska A., Kamiński P., Obuchowicz R., Piórkowski A.: Effect of Adaptive Histogram Equalization of Orthopedic Radiograph Images on the Accuracy of Implant Delineation Using Active Contours. Springer, 2021, LNNS vol 285, pp 136-144.



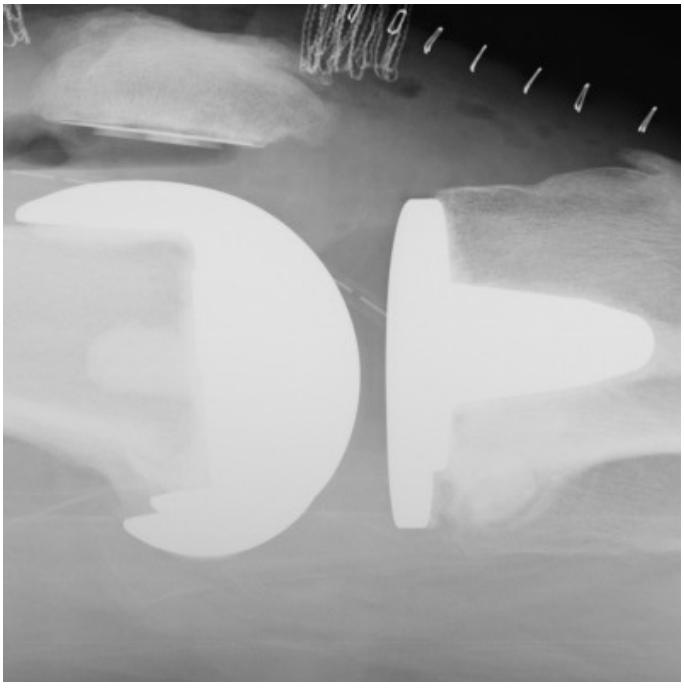


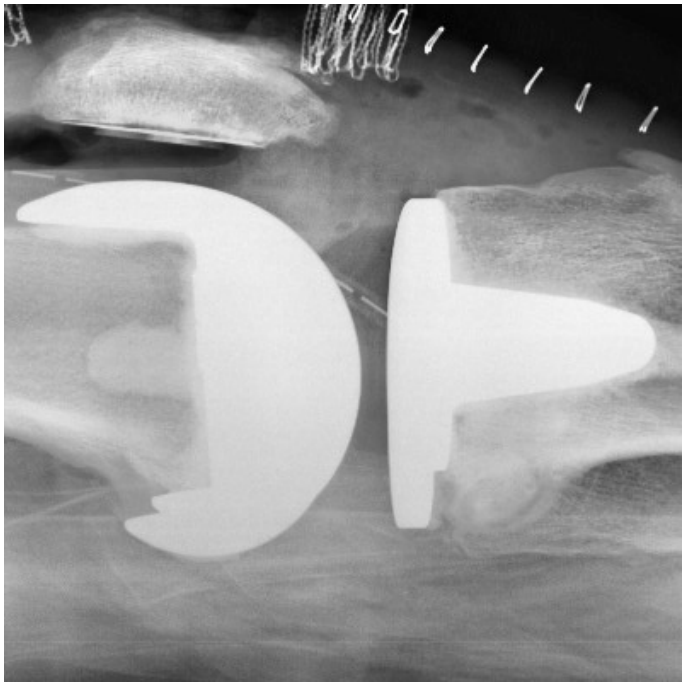
HIST EQ

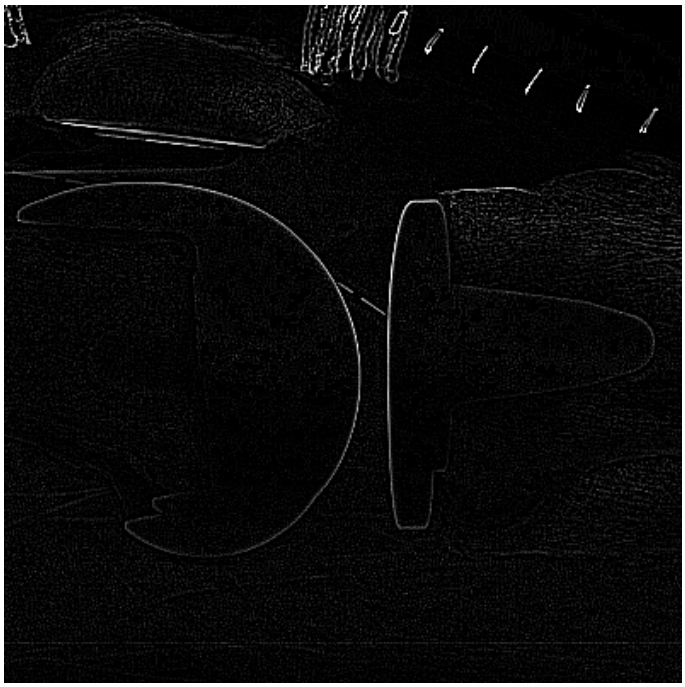
CLAHE -> HISTEQ

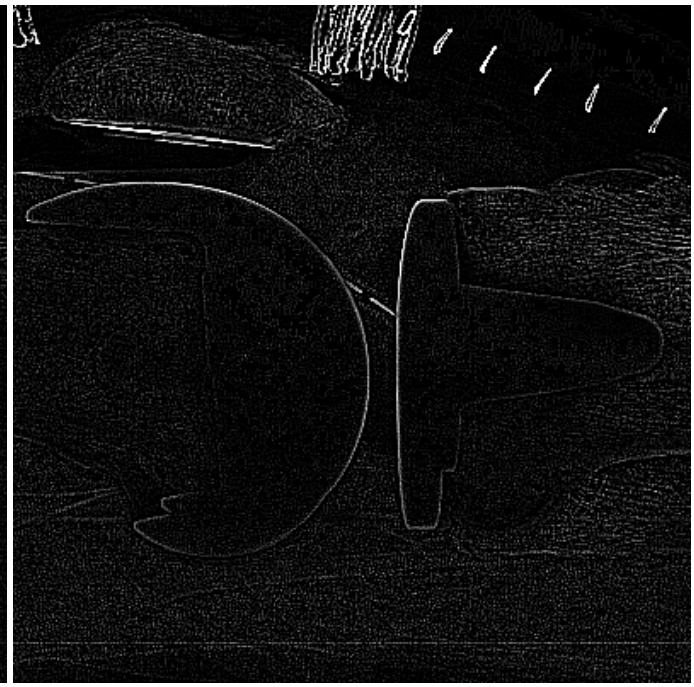
src

CLAHE









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-1	8	-1
-1	-1	-1

HIST EQ

src

CLAHE -> HISTEQ

CLAHE

Dedykowane zastosowania filtrów konwolucyjnych

-3	-3	-2	-2	-2	-2	-2	-3	-3
-3	-2	-1	-1	-1	-1	-1	-2	-3
-2	-1	0	0	0	0	0	-1	-2
-2	-1	0	6	6	6	0	-1	-2
-2	-1	0	6	40	6	0	-1	-2
-2	-1	0	6	6	6	0	-1	-2
-2	-1	0	0	0	0	0	-1	-2
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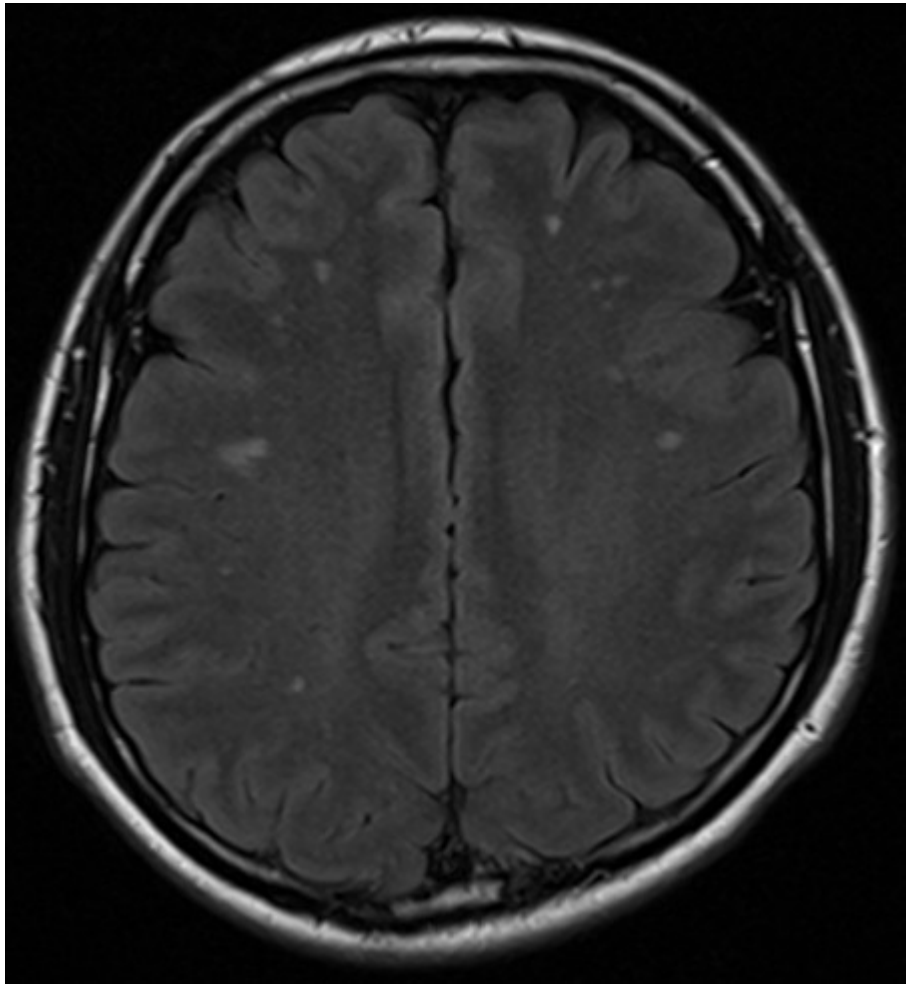
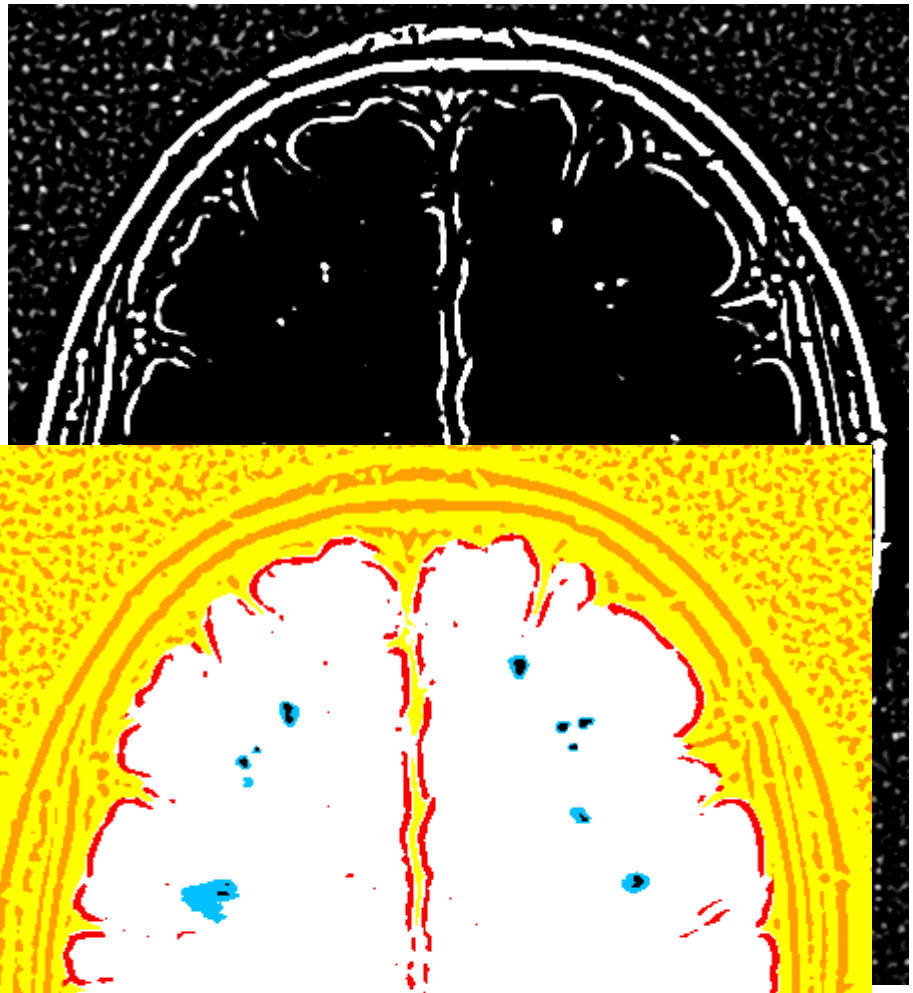
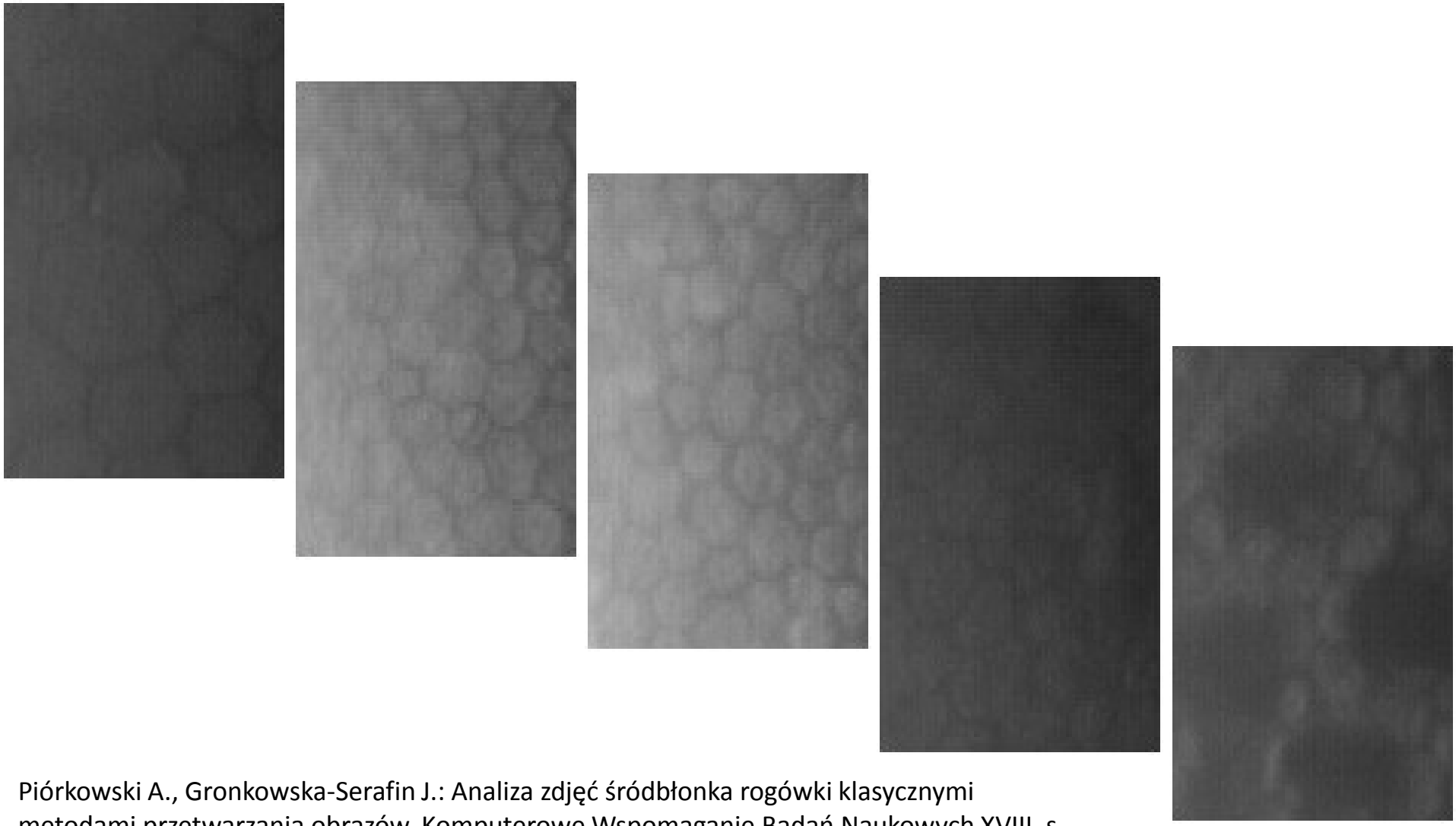
-3	-3	-2	-2	-2	-2	-2	-3	-3





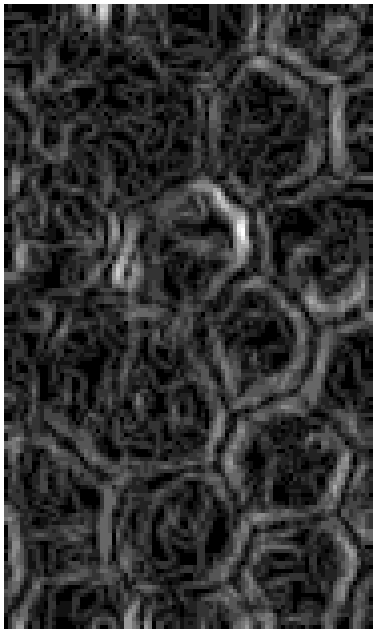
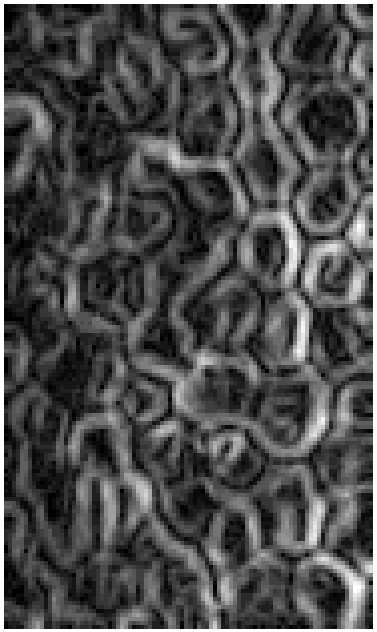
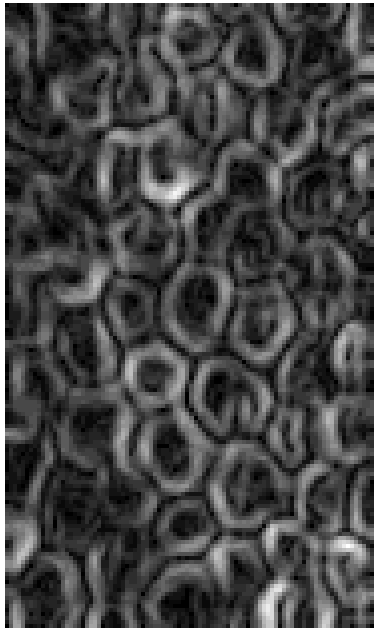
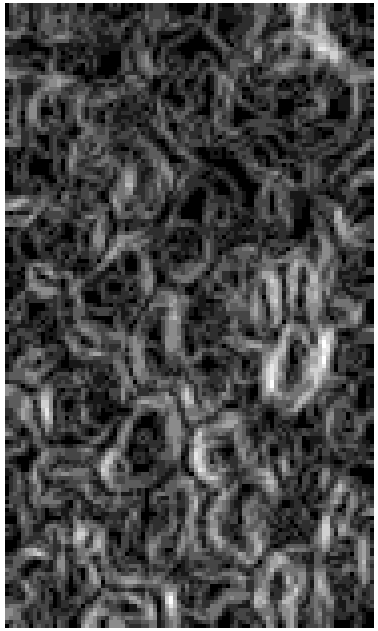
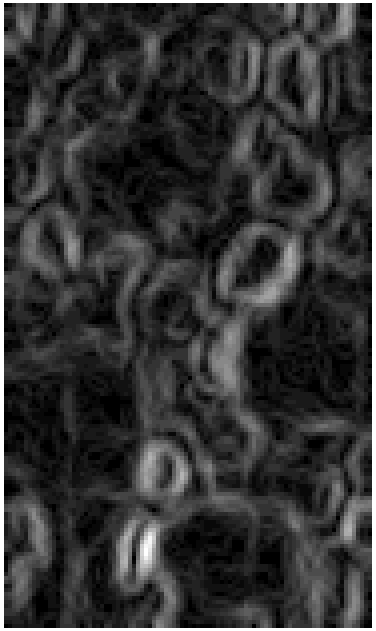
Obrazy śródbłonka rogówki



Piórkowski A., Gronkowska-Serafin J.: Analiza zdjęć śródbłonka rogówki klasycznymi metodami przetwarzania obrazów. Komputerowe Wspomaganie Badań Naukowych XVIII, s. 283-290, Wrocławskie Towarzystwo Naukowe, 2011.

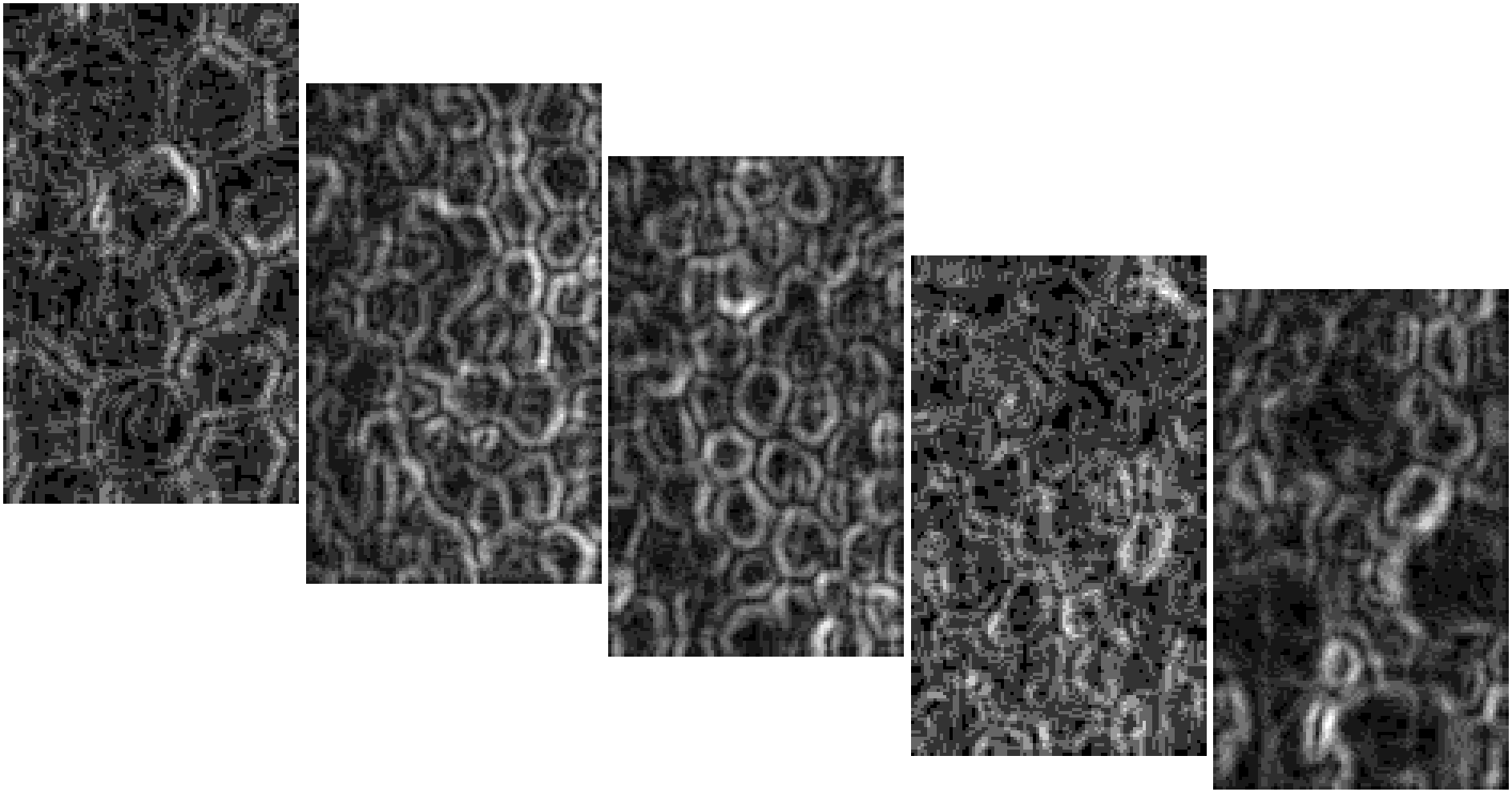
Obrazy śródbłonka rogówki

ZŁOŻENIE FILTRÓW PREWITTA

Obrazy śródbłonka rogówki

GRADIENT MORFOLOGICZNY



Obrazy śródbłonka rogówki

WYODRĘBNIANIE KOMÓREK – ‘CAPRICORN’

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

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

Mahzoun M. R., Okazaki K., Mitsumoto H., Kawai H., Sato Y., Tamura S., Kani K.: Detection and Complement of Hexagonal Borders in Corneal Endothelial Cell Image. Medical Imaging Technology, Vol. 14 No. 1, January 1996

Obrazy śródbłonka rogówki

PROPONOWANA MASKA

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3	2	1	1	1	1	1	2	3
2	1	0	0	0	0	0	1	2
2	1	0	-6	-12	-6	0	1	2
2	1	0	-12	-32	-12	0	1	2
2	1	0	-6	-12	-6	0	1	2
2	1	0	0	0	0	0	1	2
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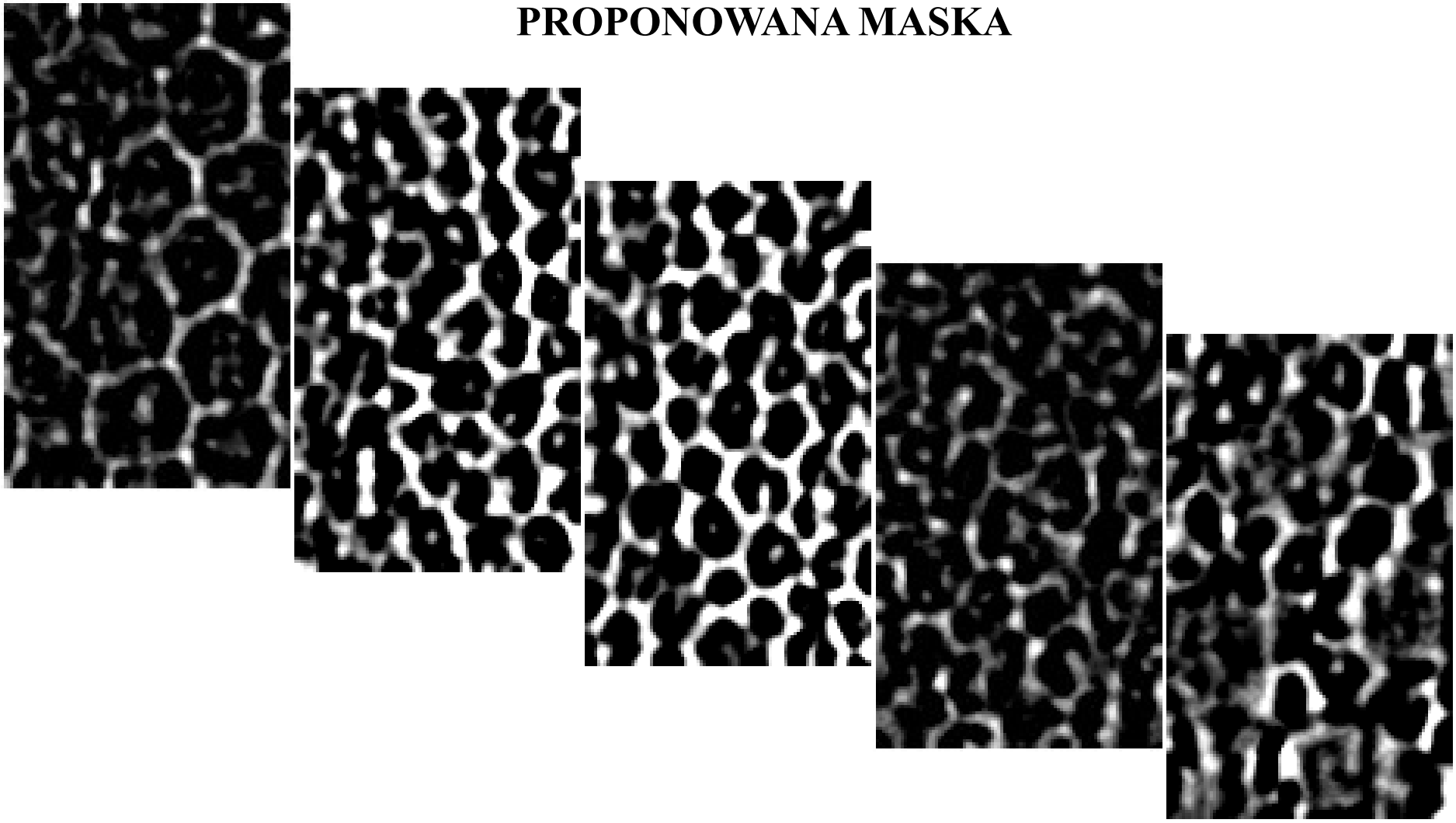
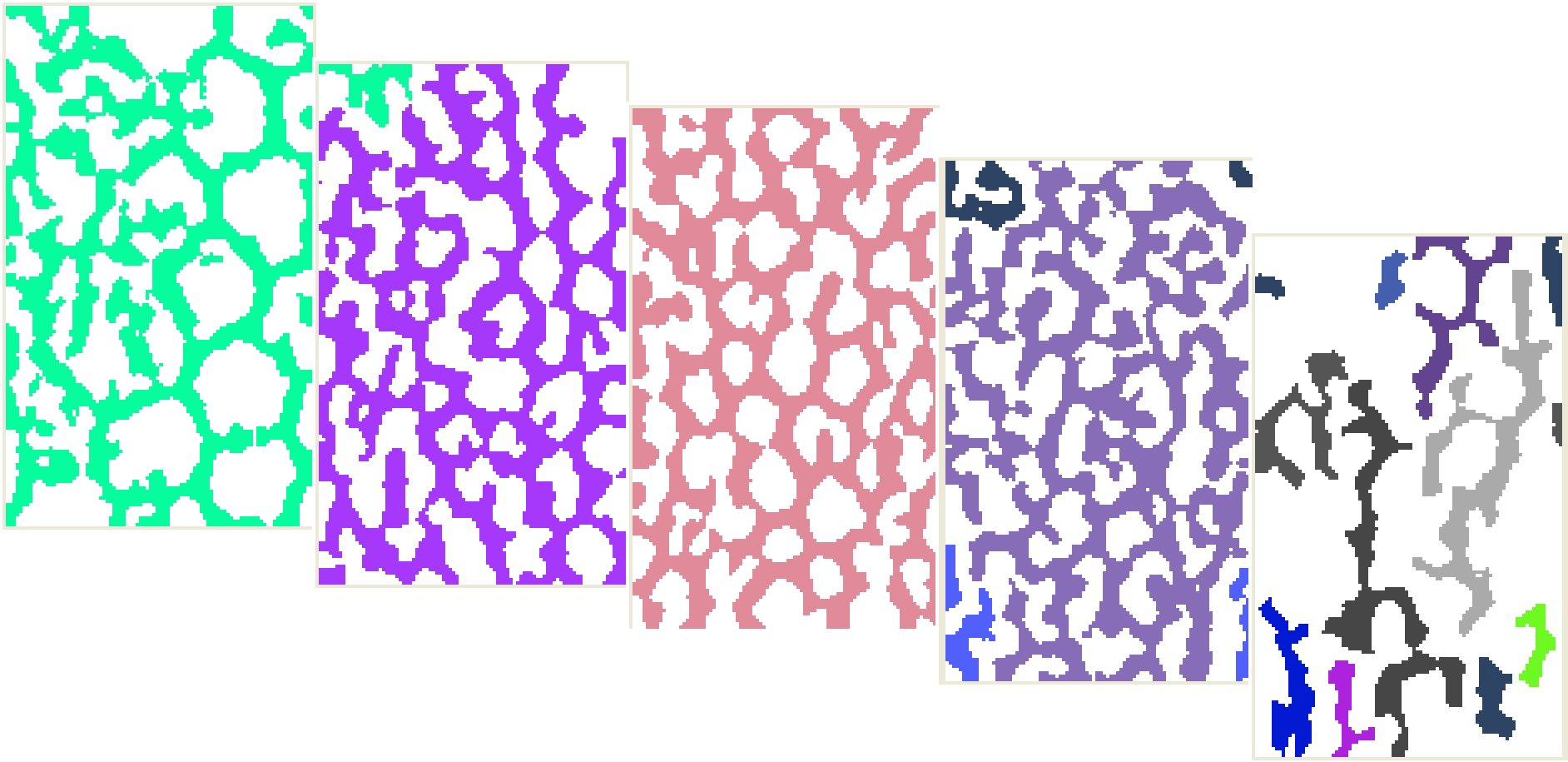
3	3	2	2	2	2	2	3	3

Obrazy śródbłonka rogówki



Obrazy śródbłonka rogówki

INDEKSACJA BRZEGÓW MIĘDZYKOMÓRKOWYCH



Obrazy śródbłonka rogówki

WYODRĘBNIANIE KOMÓREK

-3	-3	-2	-2	-2	-2	-2	-3	-3
-3	-2	-1	-1	-1	-1	-1	-2	-3
-2	-1	0	0	0	0	0	-1	-2
-2	-1	0	6	12	6	0	-1	-2
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-2	-1	0	0	0	0	0	-1	-2
-3	-2	-1	-1	-1	-1	-1	-2	-3
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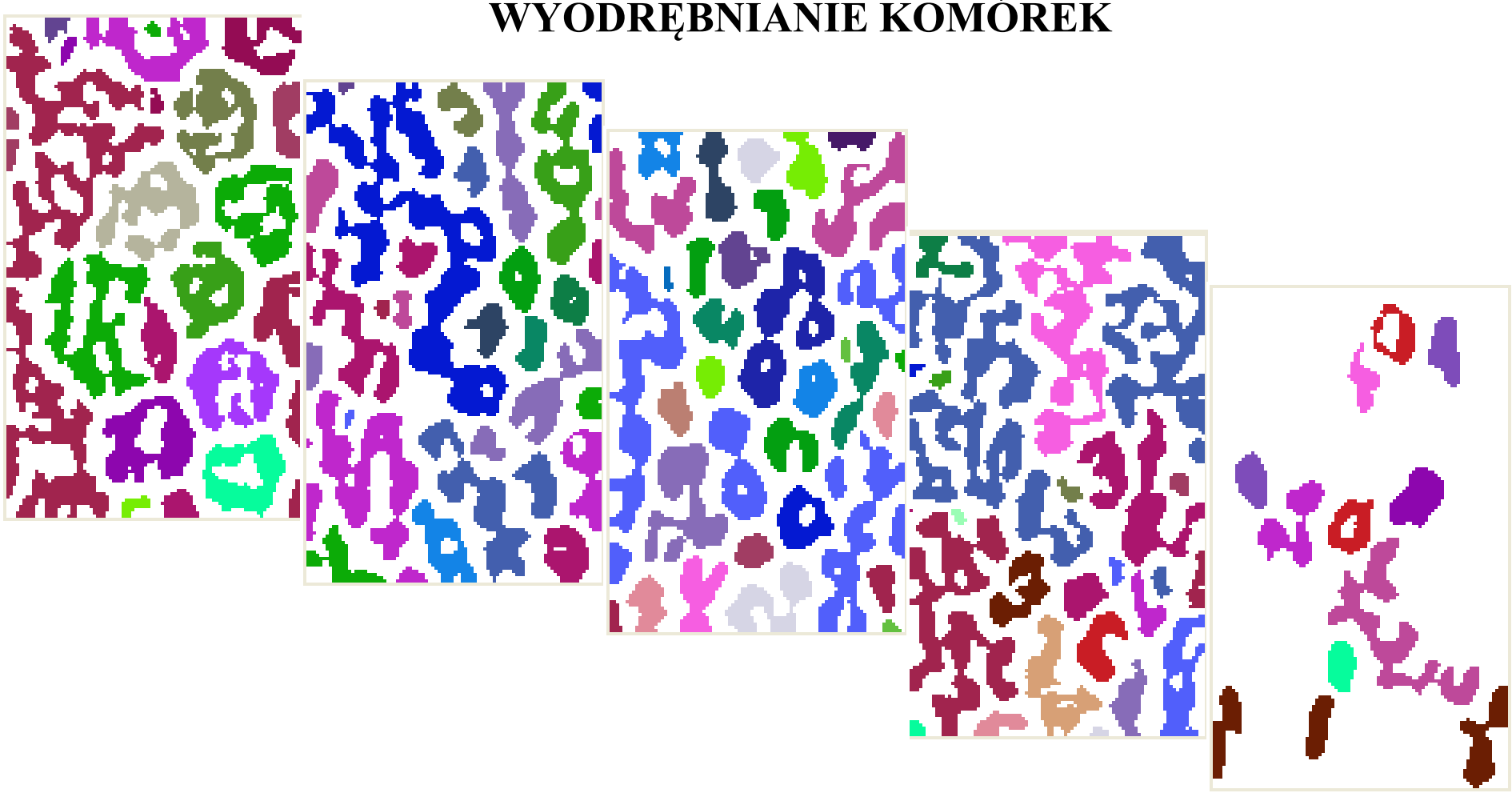
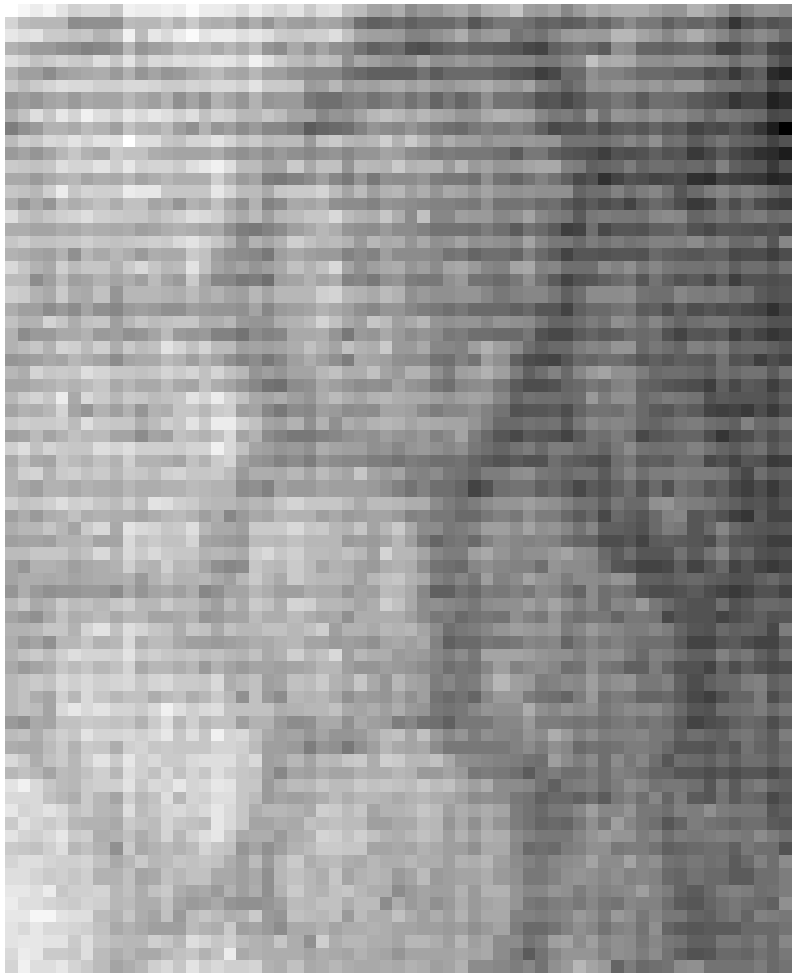
Obrazy śródbłonka rogówki

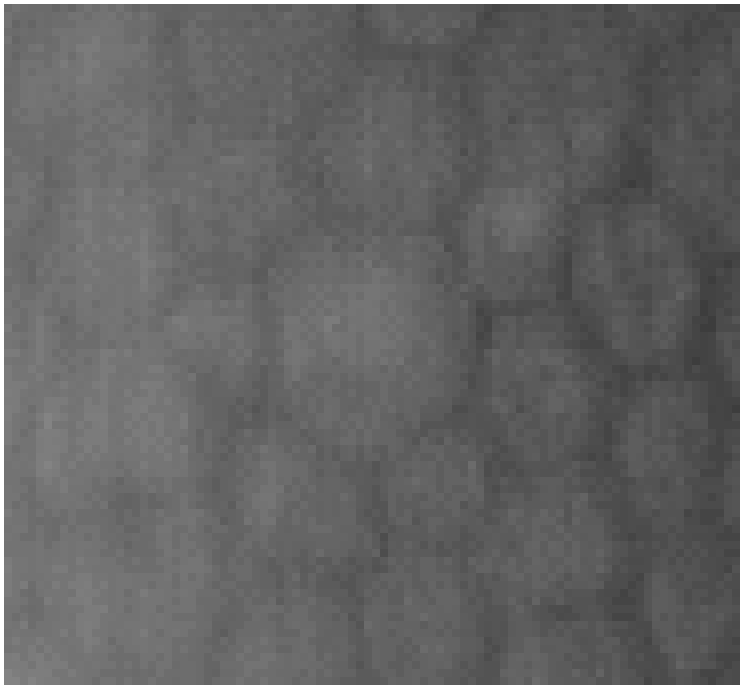


Corneal endothelium images

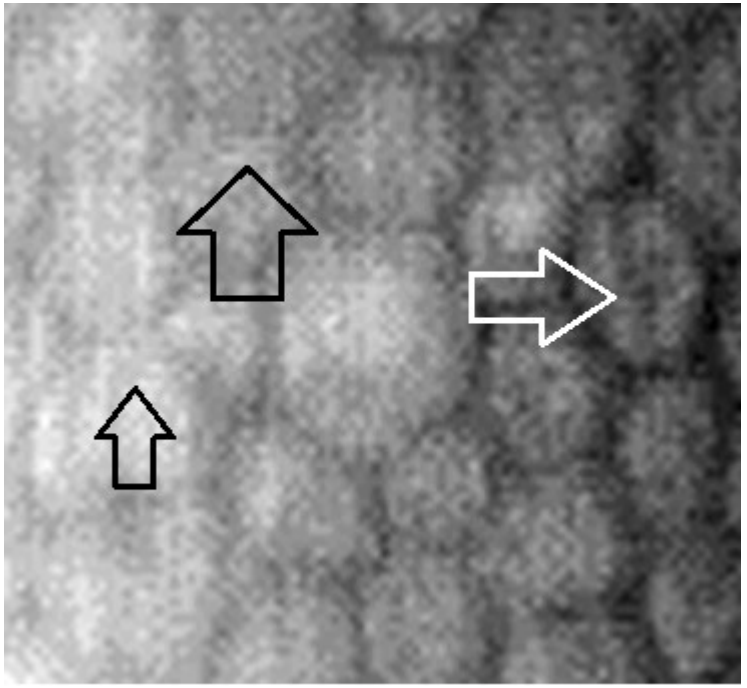


K. Habrat, M. Habrat, J. Gronkowska-Serafin, A. Piorkowski: Cell Detection in Corneal Endothelial Images Using Directional Filters. Springer 2016, AISC Vol. 389, pp 113–123.

Corneal endothelium images

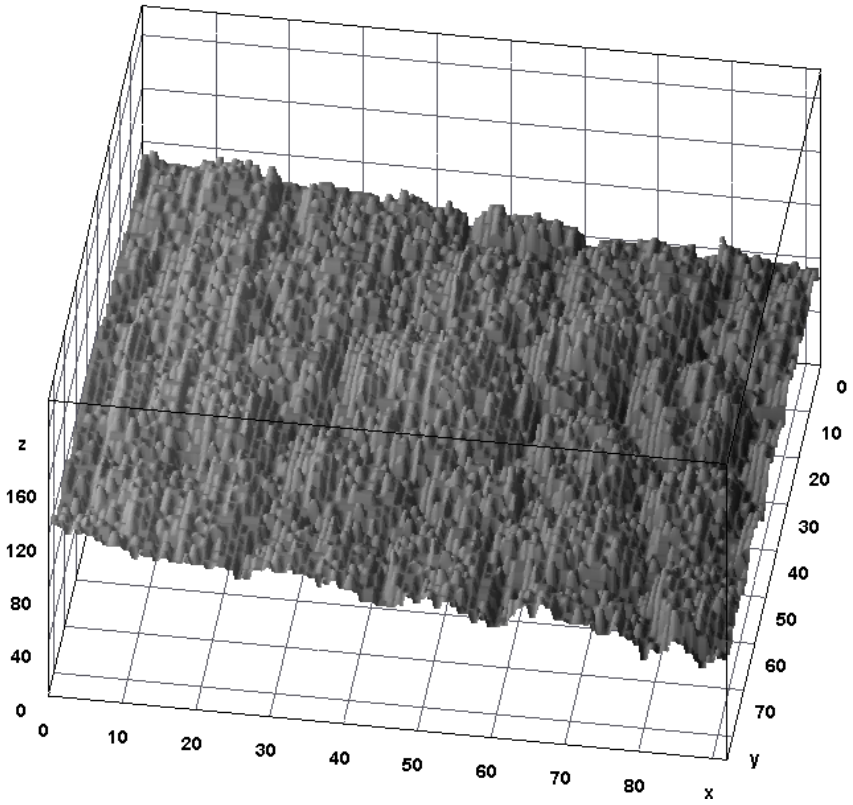


original



normalized

Corneal endothelium images



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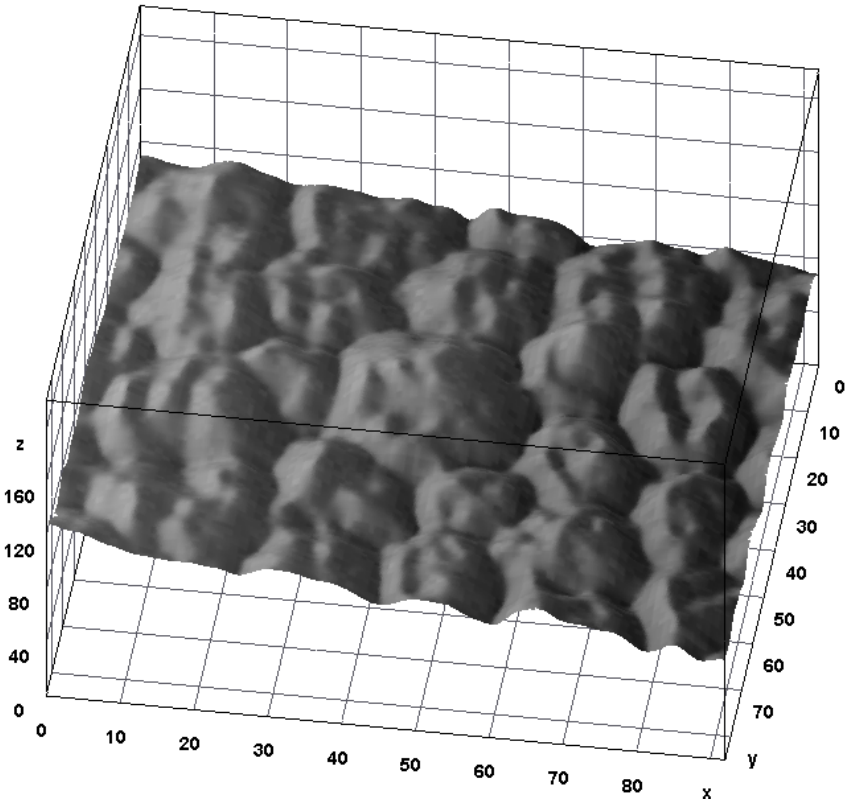
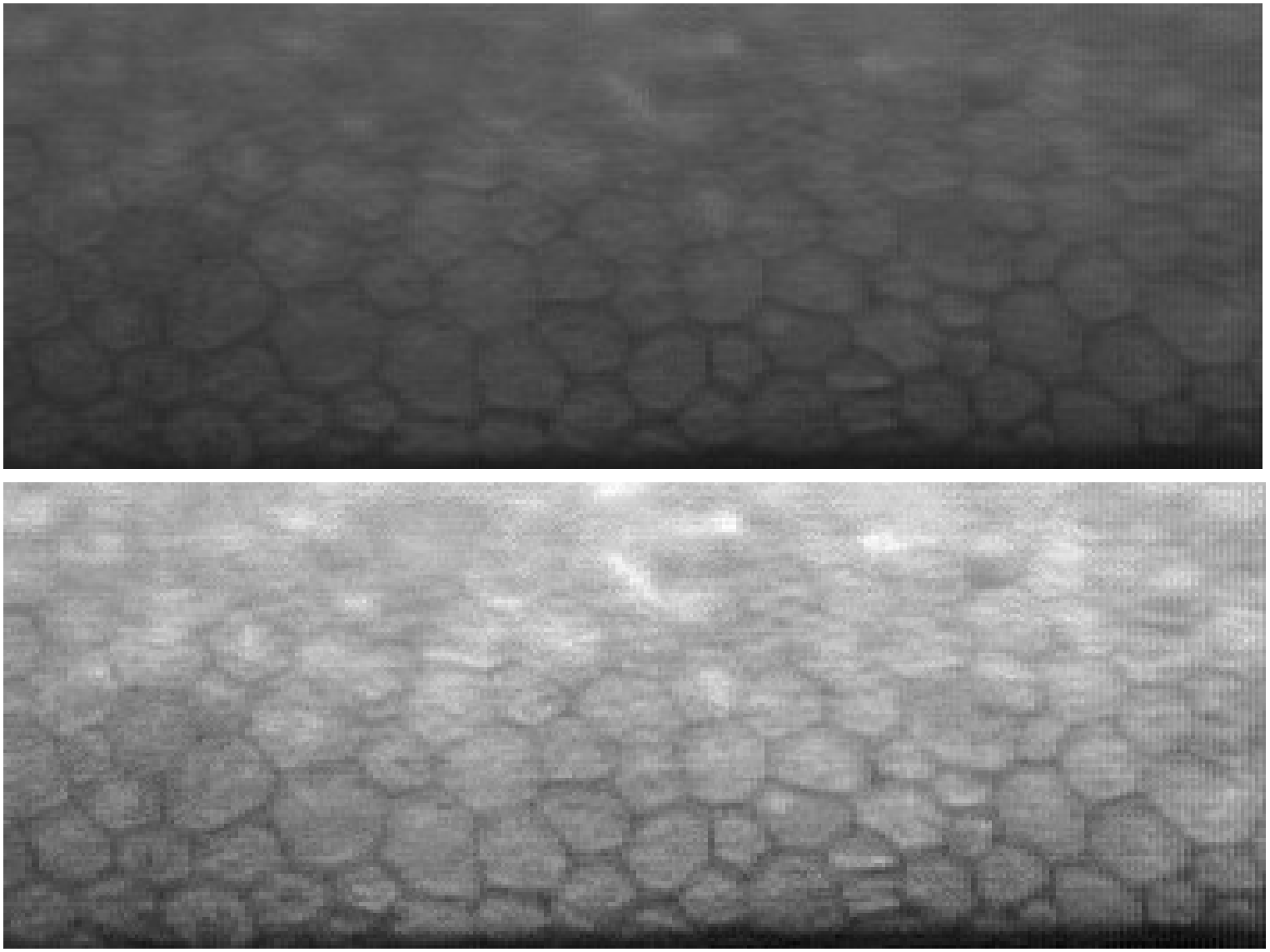
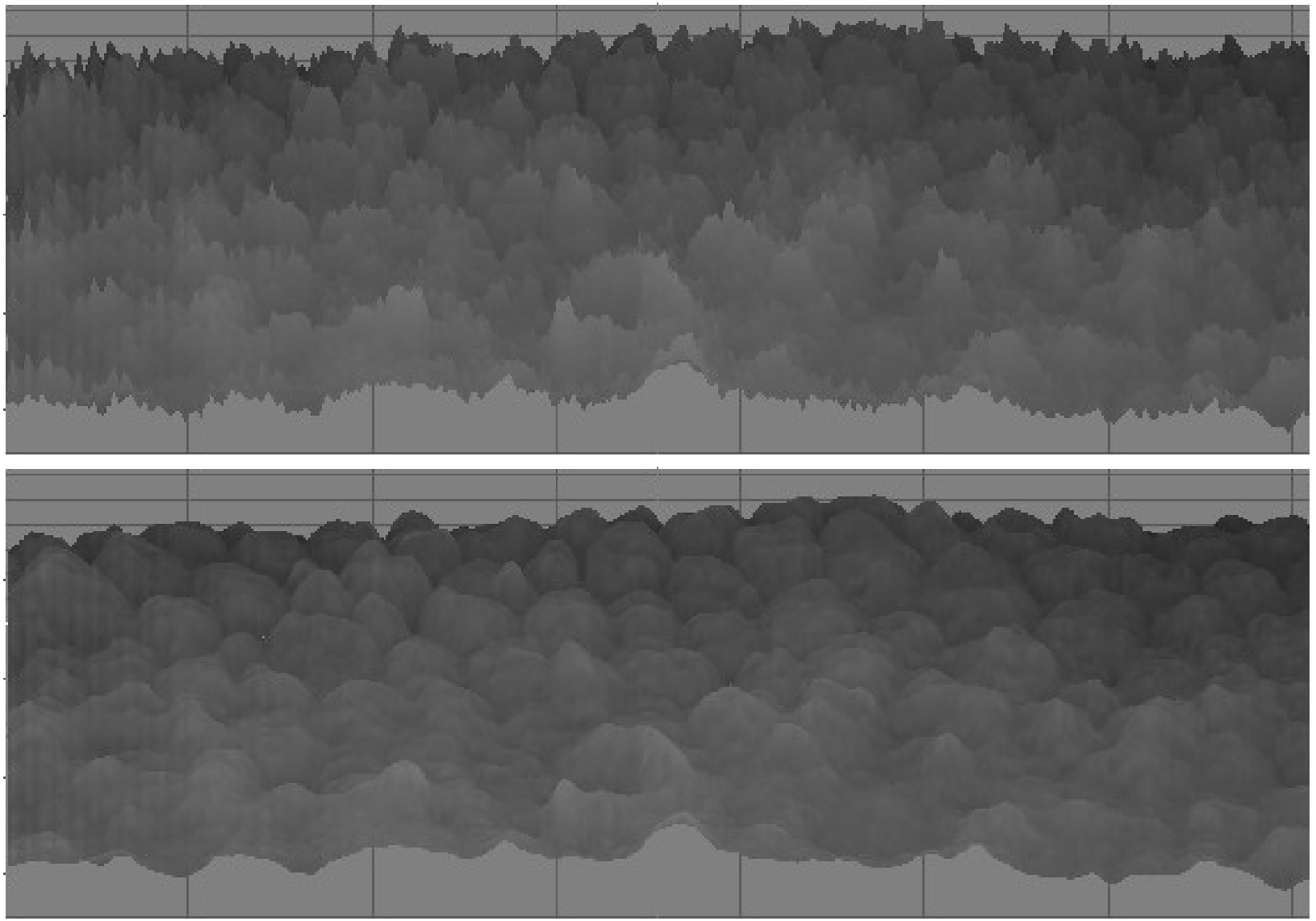


after preprocessing (smoothing)

Corneal endothelium images



Corneal endothelium images



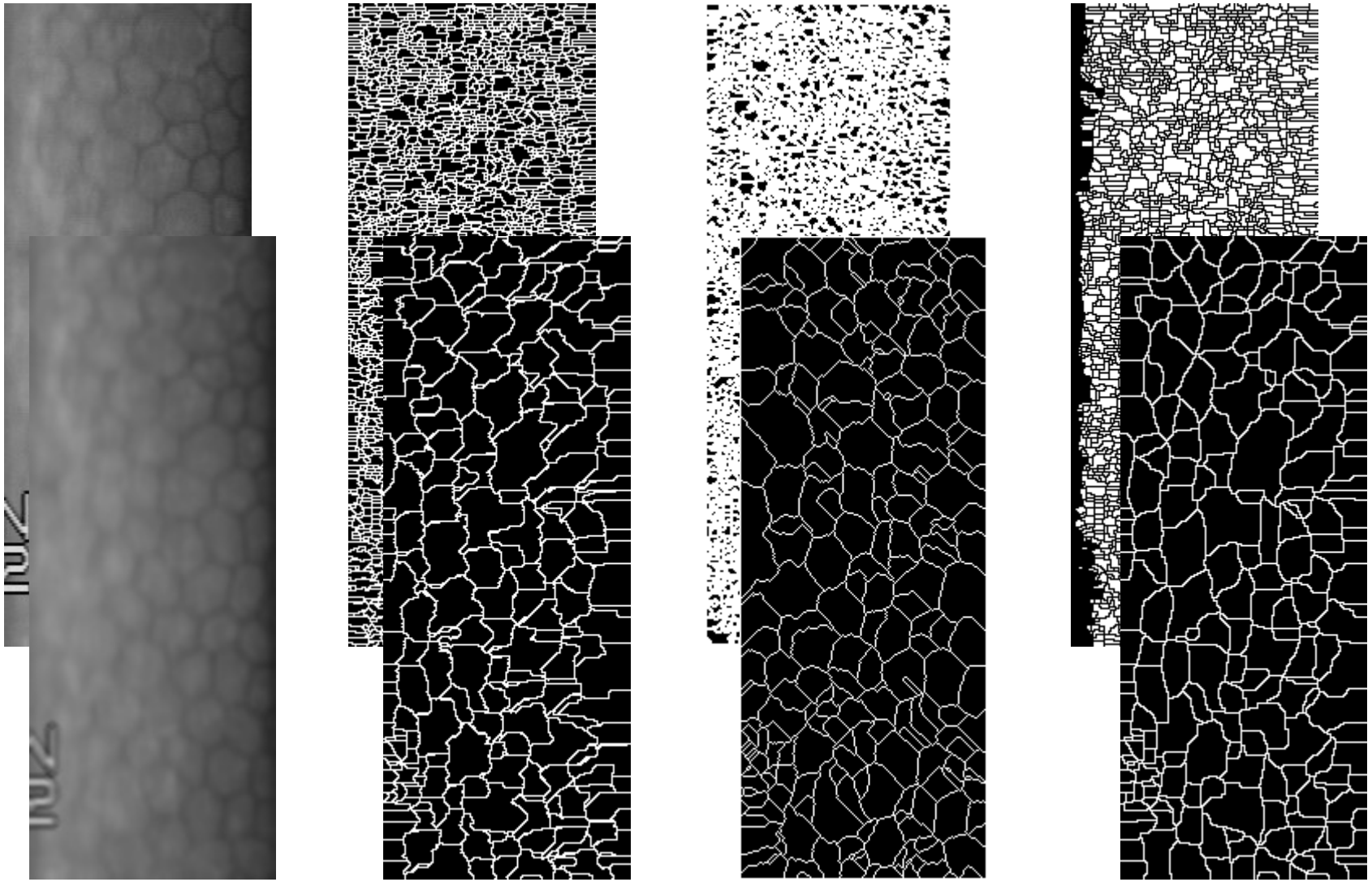
after smoothing

Corneal endothelium images

ImageJ

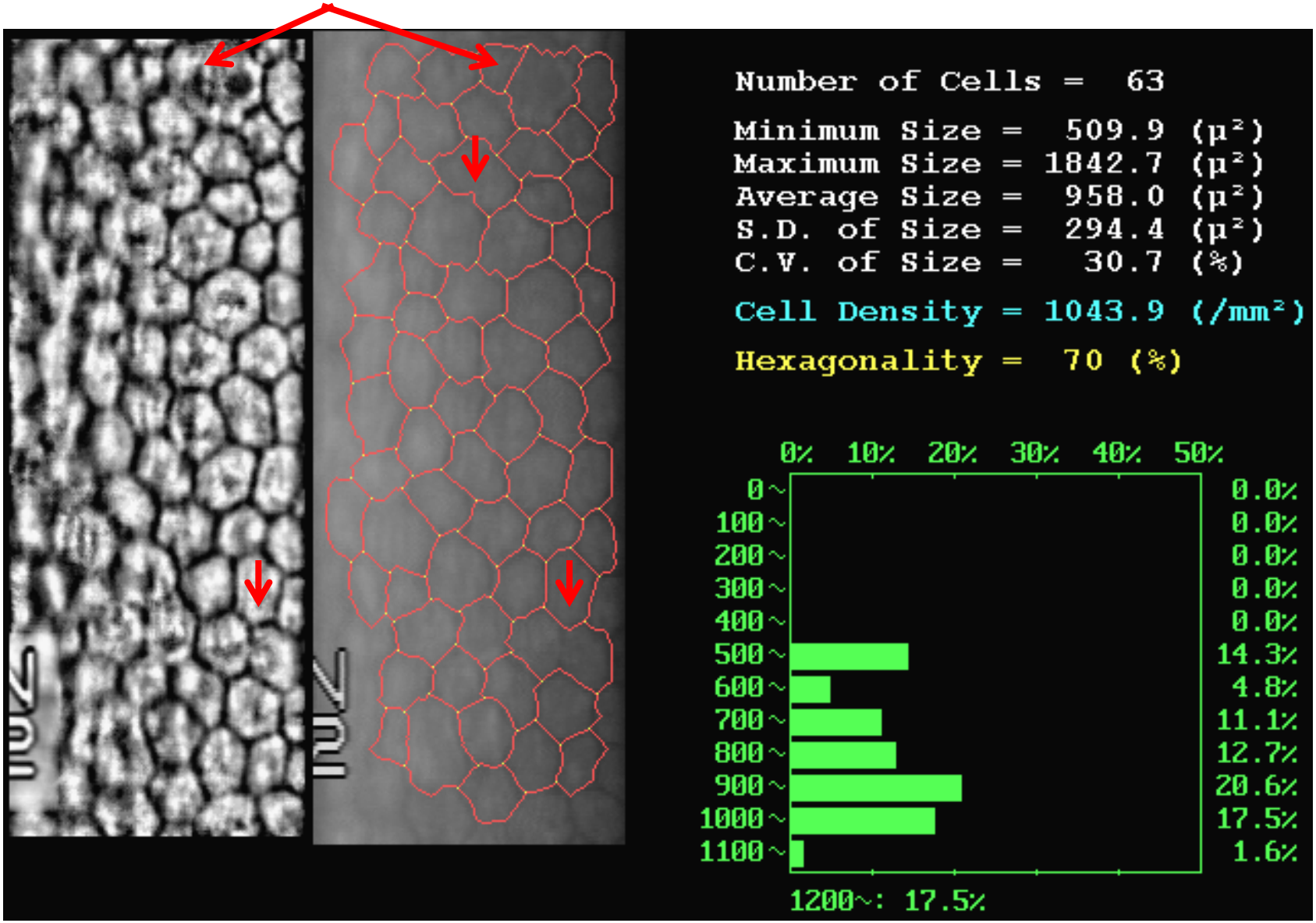
ImageJ - BIG

Matlab ☺

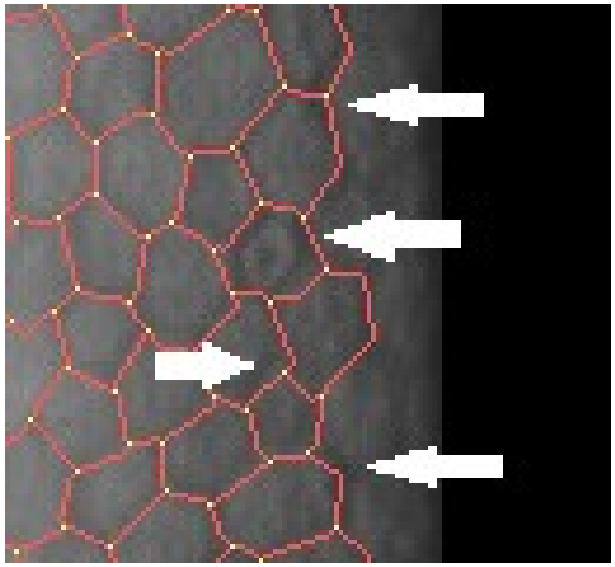


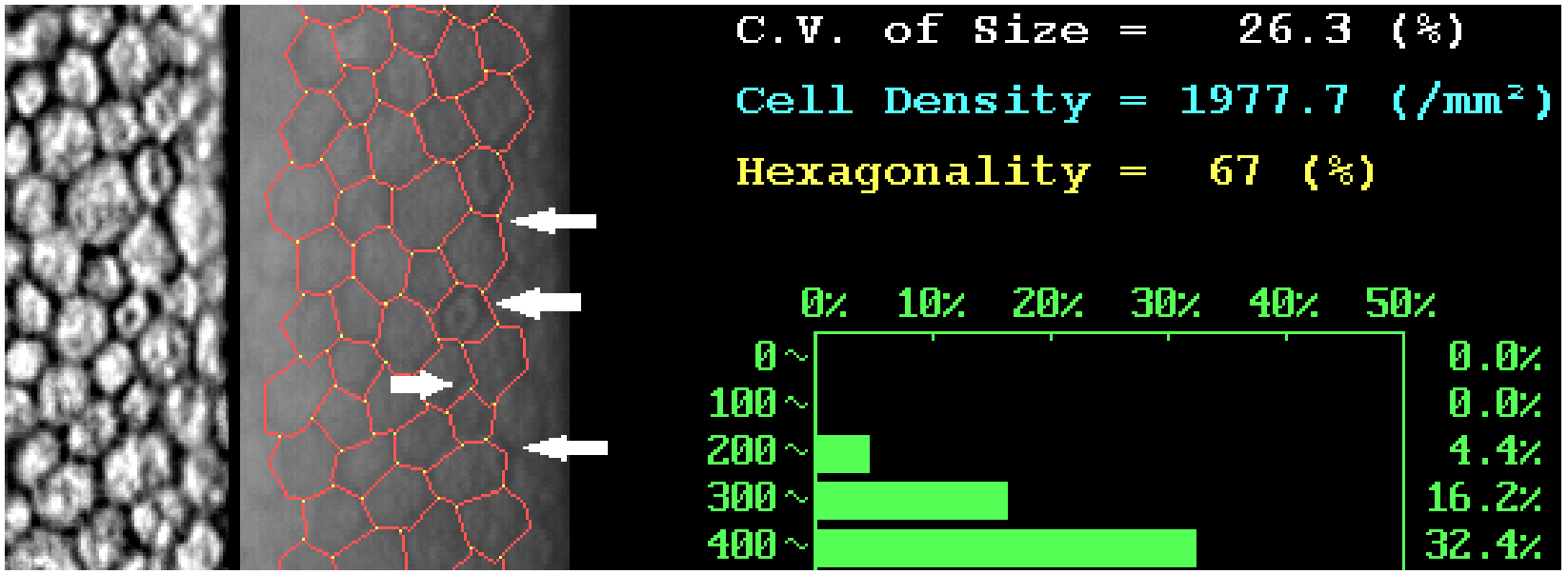
After smoothing

Corneal endothelium images



Corneal endothelium images





Preprocessing

$$S = \frac{\sum_{i=1}^{x} \sum_{j=1}^{y} Pin_{ij}}{xy} \tag{1}$$

$$Sw_j = \sum_{i=1}^{x} Pin_{ij} \tag{2}$$

$$Sk_j = \sum_{j=1}^{y} Pin_{ij} \tag{3}$$

$$Pout_{ij} = \begin{Bmatrix} Pin_{ij} + S - Sw_j & for\ Sw_j \neq S \\ Pin_{ij} & for\ Sw_j = S \end{Bmatrix} \tag{4}$$

$$Pout_{ij} = \begin{Bmatrix} Pin_{ij} + S - Sk_i & for\ Sk_i \neq S \\ Pin_{ij} & for\ Sk_i = S \end{Bmatrix} \tag{5}$$

Preprocessing

$$Pout_{ij} = \begin{cases} Pin_{ij} + S - Sw_j & for\ Sw_j > S \\ Pin_{ij} & for\ Sw_j = S \\ \frac{Pin_{ij} S}{Sw_j} & for\ Sw_j < S \end{cases} \quad (6)$$

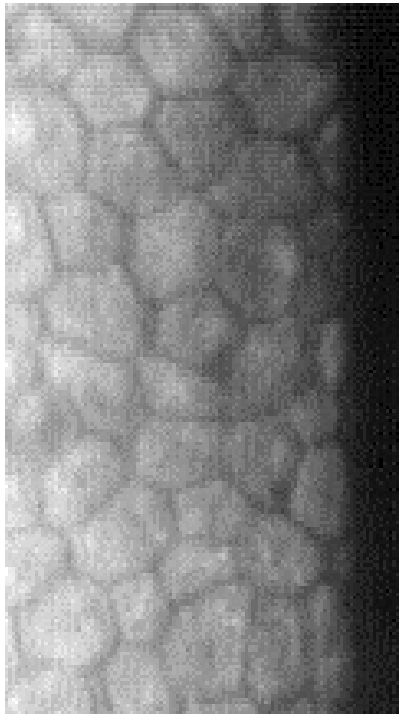
$$Pout_{ij} = \begin{cases} Pin_{ij} + S - Sk_i & for\ Sk_i > S \\ Pin_{ij} & for\ Sk_i = S \\ \frac{Pin_{ij} S}{Sk_i} & for\ Sk_i < S \end{cases} \quad (7)$$

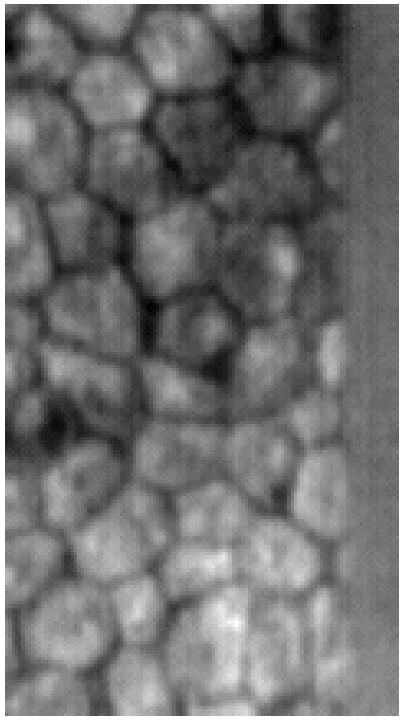
$$Pout_{ij} = \begin{cases} Pin_{ij} + S - Sk_i & for\ Sk_i > S \\ Pin_{ij} & for\ Sk_i = S \\ \frac{Pin_{ij} S}{Sk_i} & for\ Sk_i < S \end{cases} \quad (8)$$

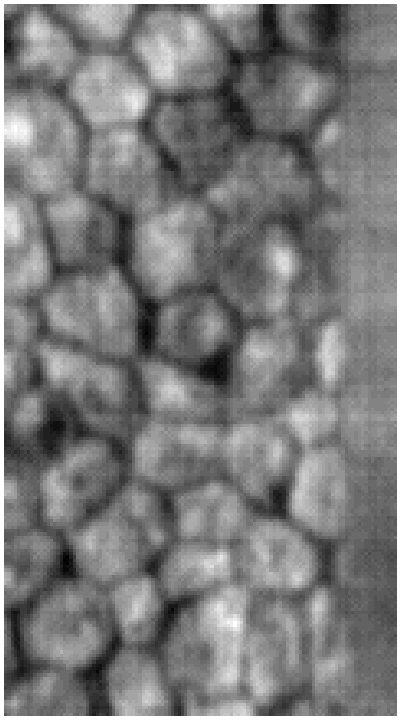
$$Pout_{ij} = Pin_{ij} + (S - Sr_{ij}) \quad (9)$$

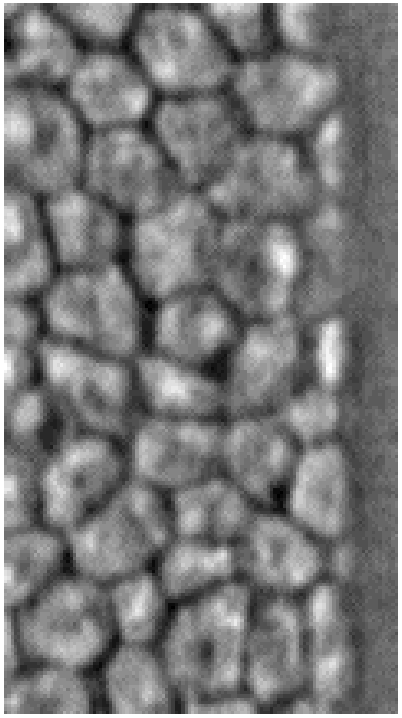
dodanie różnicy średniej obrazu (S) i średniej w kole o promieniu r dla piksela i,j (Srij) (9)

Preprocessing





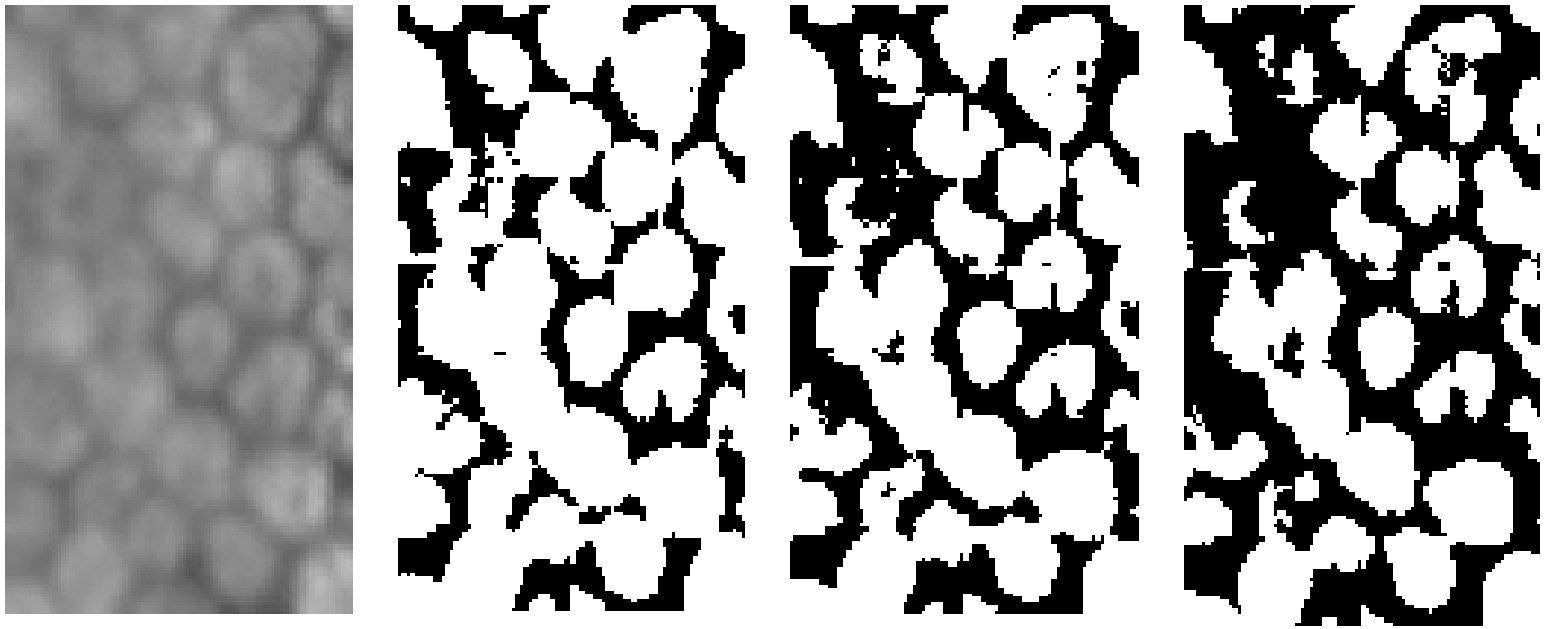




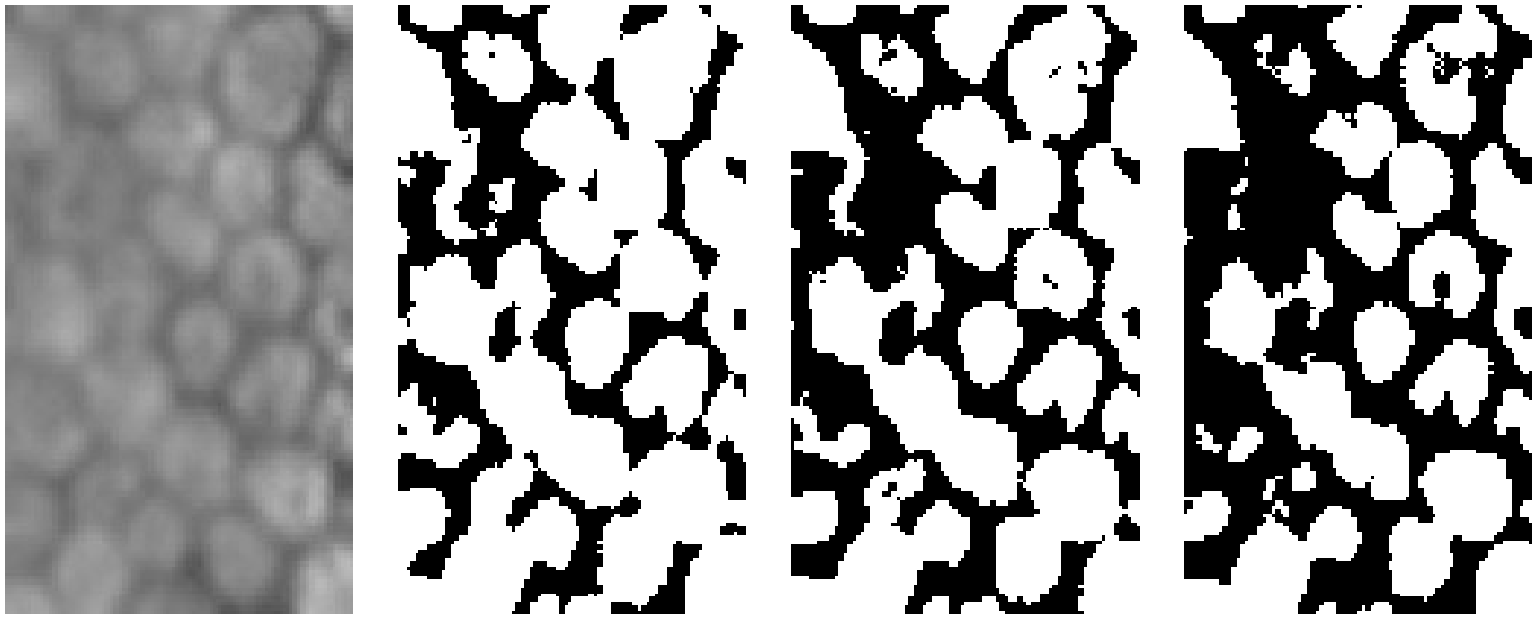
dodanie różnicy średniej obrazu
i średniej w kole (9)

r=10

Adaptive binarization

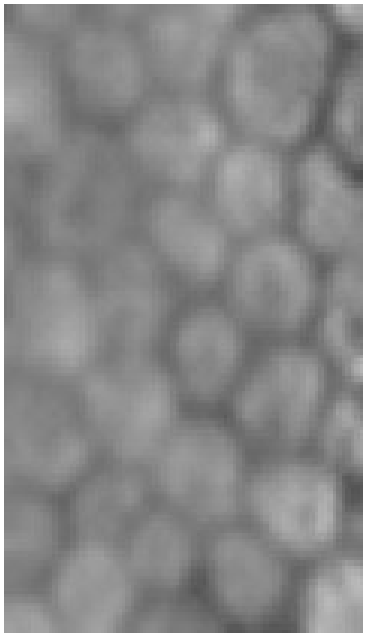


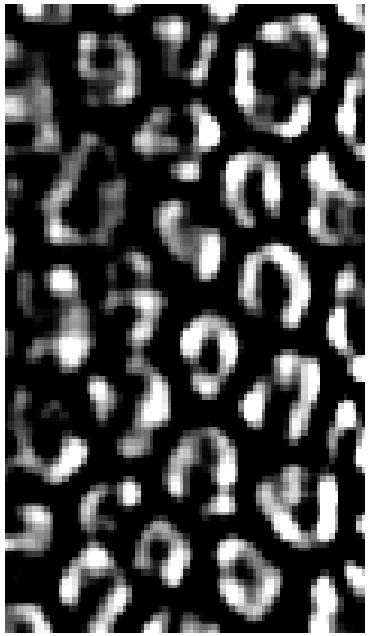
Top-Hat



Single 9x9 mask

$$\begin{bmatrix} -3 & -3 & -2 & -2 & -2 & -2 & -2 & -3 & -3 \\ -3 & -2 & -1 & -1 & -1 & -1 & -1 & -2 & -3 \\ -2 & -1 & 0 & 0 & 0 & 0 & 0 & -1 & -2 \\ -2 & -1 & 0 & 6 & 12 & 6 & 0 & -1 & -2 \\ -2 & -1 & 0 & 12 & 32 & 12 & 0 & -1 & -2 \\ -2 & -1 & 0 & 6 & 12 & 6 & 0 & -1 & -2 \\ -2 & -1 & 0 & 0 & 0 & 0 & 0 & -1 & -2 \\ -3 & -2 & -1 & -1 & -1 & -1 & -1 & -2 & -3 \\ -3 & -3 & -2 & -2 & -2 & -2 & -2 & -3 & -3 \end{bmatrix}$$





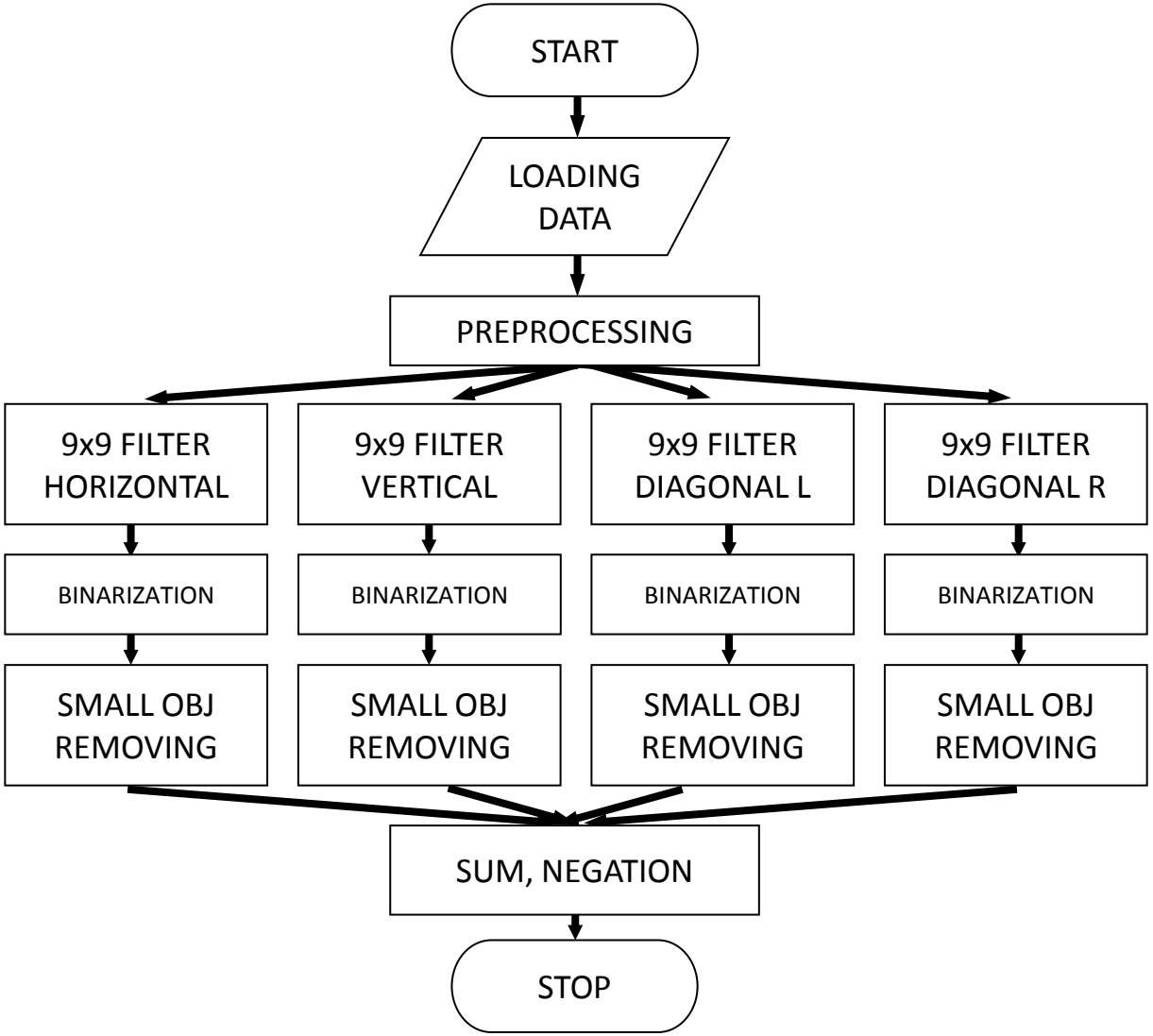
KH Algorithm

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 22 & -2 & -4 & -8 & -16 & -8 & -4 & -2 & 22 \\ 22 & -2 & -4 & -8 & -16 & -8 & -4 & -2 & 22 \\ 22 & -2 & -4 & -8 & -16 & -8 & -4 & -2 & 22 \\ 22 & -2 & -4 & -8 & -16 & -8 & -4 & -2 & 22 \\ 22 & -2 & -4 & -8 & -16 & -8 & -4 & -2 & 22 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \quad \begin{bmatrix} 0 & 0 & 22 & 22 & 22 & 22 & 22 & 0 & 0 \\ 0 & 0 & -2 & -2 & -2 & -2 & -2 & 0 & 0 \\ 0 & 0 & -4 & -4 & -4 & -4 & -4 & 0 & 0 \\ 0 & 0 & -8 & -8 & -8 & -8 & -8 & 0 & 0 \\ 0 & 0 & -16 & -16 & -16 & -16 & -16 & 0 & 0 \\ 0 & 0 & -8 & -8 & -8 & -8 & -8 & 0 & 0 \\ 0 & 0 & -4 & -4 & -4 & -4 & -4 & 0 & 0 \\ 0 & 0 & -2 & -2 & -2 & -2 & -2 & 0 & 0 \\ 0 & 0 & 22 & 22 & 22 & 22 & 22 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 22 & 22 & 22 & 0 & 0 & 0 & 0 & 0 & 0 \\ 22 & -2 & -2 & -2 & 0 & 0 & 0 & 0 & 0 \\ 22 & -2 & -4 & -4 & -4 & -8 & -16 & 0 & 0 \\ 0 & -2 & -4 & -8 & -8 & -16 & -8 & 0 & 0 \\ 0 & 0 & -4 & -8 & -16 & -8 & -4 & 0 & 0 \\ 0 & 0 & -8 & -16 & -8 & -8 & -4 & -2 & 0 \\ 0 & 0 & -16 & -8 & -4 & -4 & -4 & -2 & 22 \\ 0 & 0 & 0 & 0 & 0 & -2 & -2 & -2 & 22 \\ 0 & 0 & 0 & 0 & 0 & 0 & 22 & 22 & 22 \end{bmatrix} \quad \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 22 & 22 & 22 \\ 0 & 0 & 0 & 0 & 0 & -2 & -2 & -2 & 22 \\ 0 & 0 & -16 & -8 & -4 & -4 & -4 & -2 & 22 \\ 0 & 0 & -8 & -16 & -8 & -8 & -4 & -2 & 0 \\ 0 & 0 & -4 & -8 & -16 & -8 & -4 & 0 & 0 \\ 0 & -2 & -4 & -8 & -8 & -16 & -8 & 0 & 0 \\ 22 & -2 & -4 & -4 & -4 & -8 & -16 & 0 & 0 \\ 22 & -2 & -2 & -2 & 0 & 0 & 0 & 0 & 0 \\ 22 & 22 & 22 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

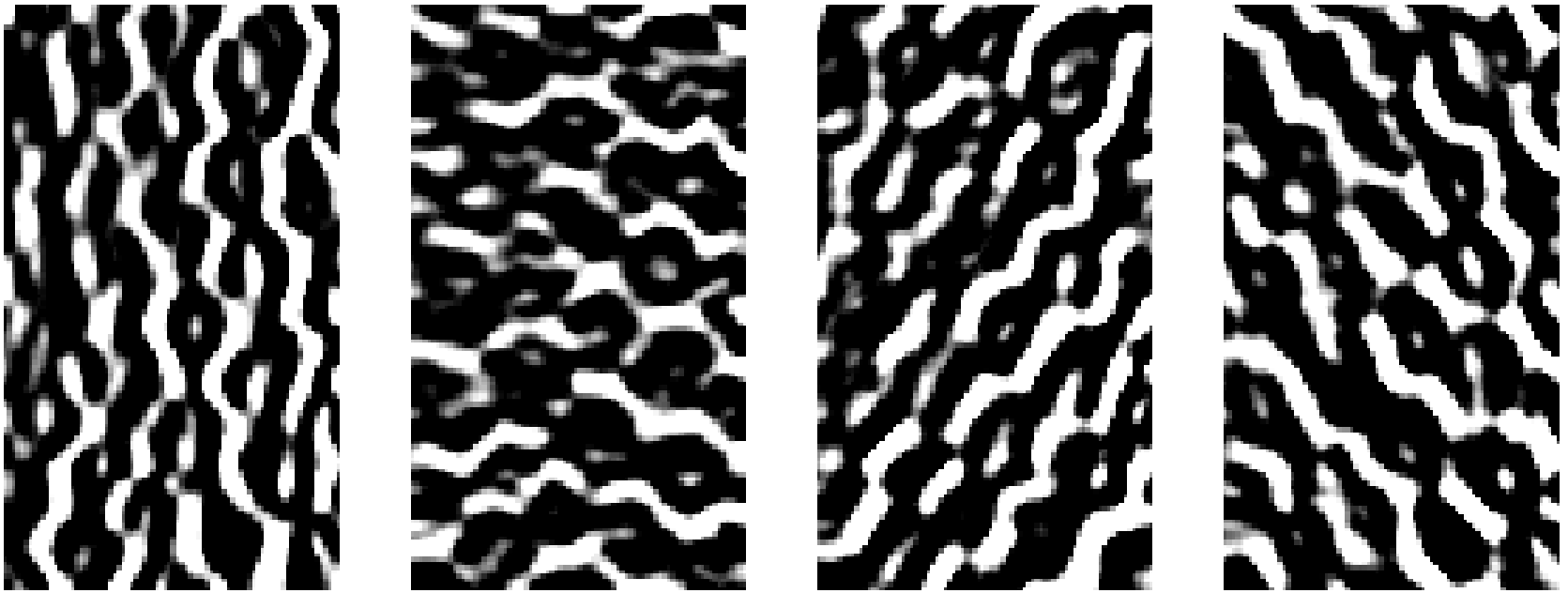
K. Habrat, M. Habrat, J. Gronkowska-Serafin, A. Piorkowski: Cell Detection In Corneal Endothelial Images Using Directional Filters. Springer 2016, AISC Vol. 389, pp 113–123.

KH Algorithm



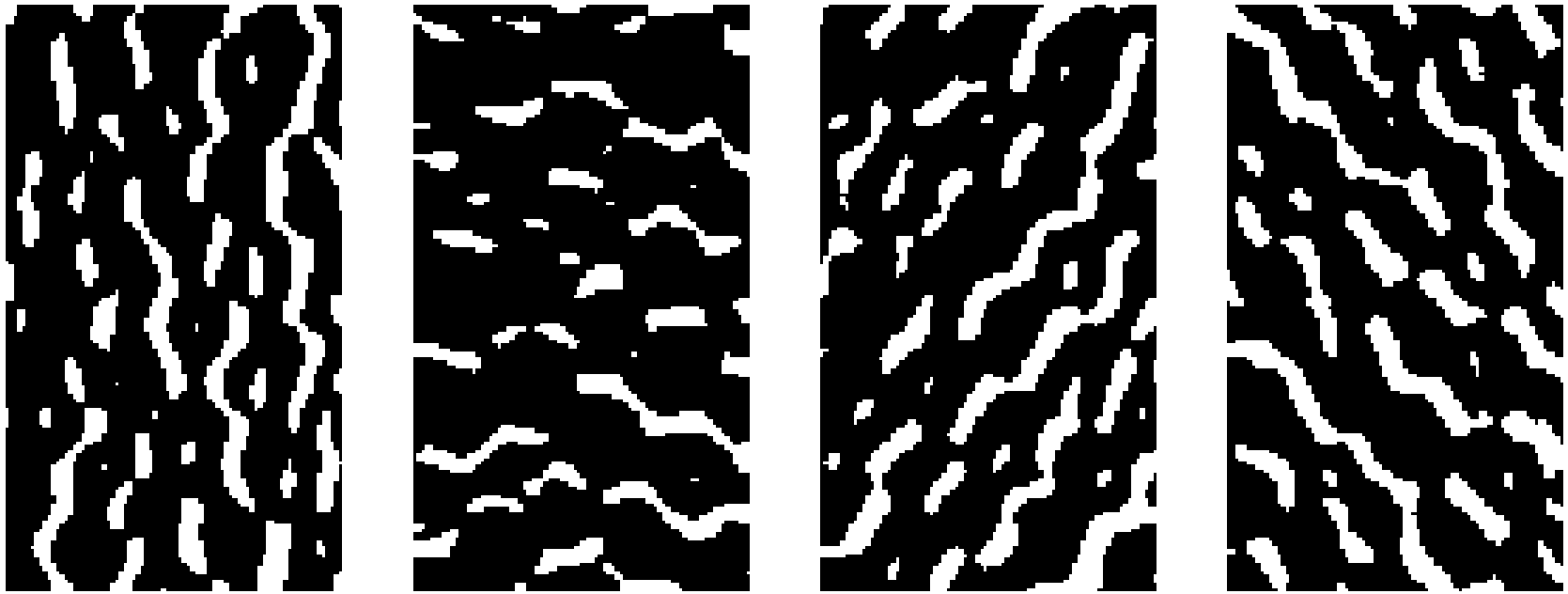
KH Algorithm

… using masks



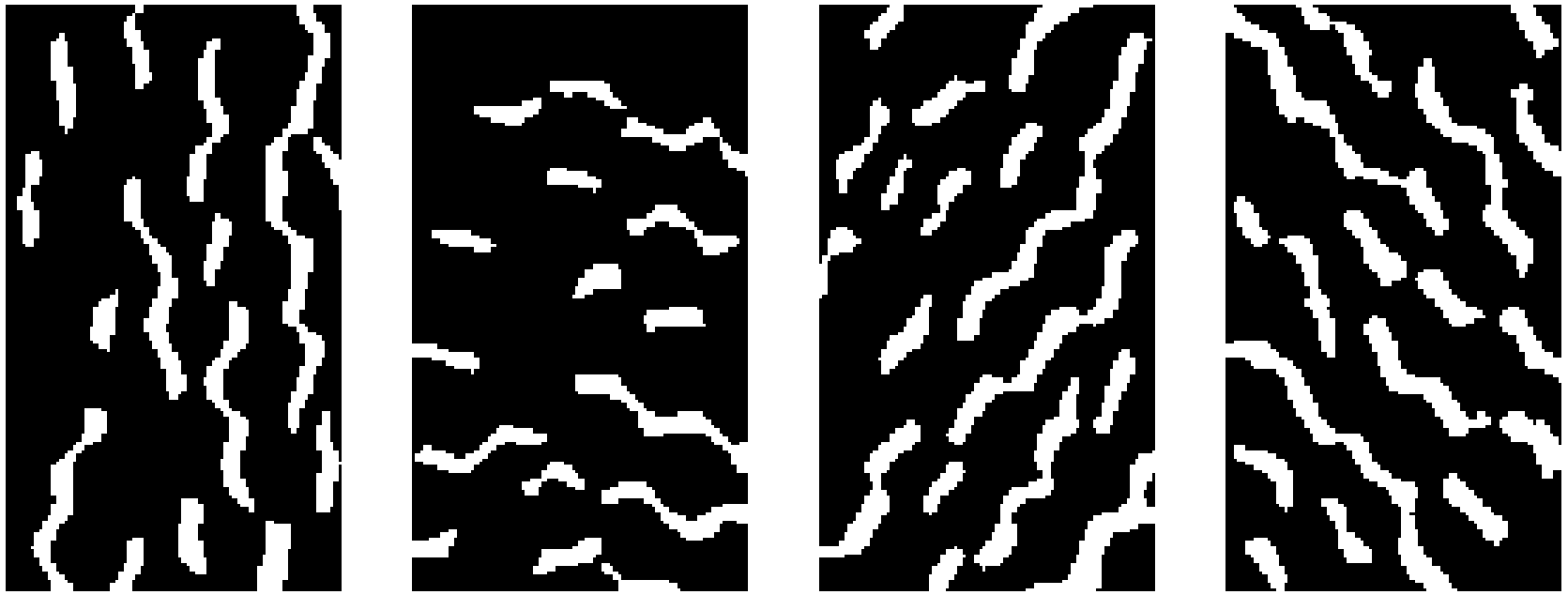
KH Algorithm

… and next the binarizaton (~50% of range)



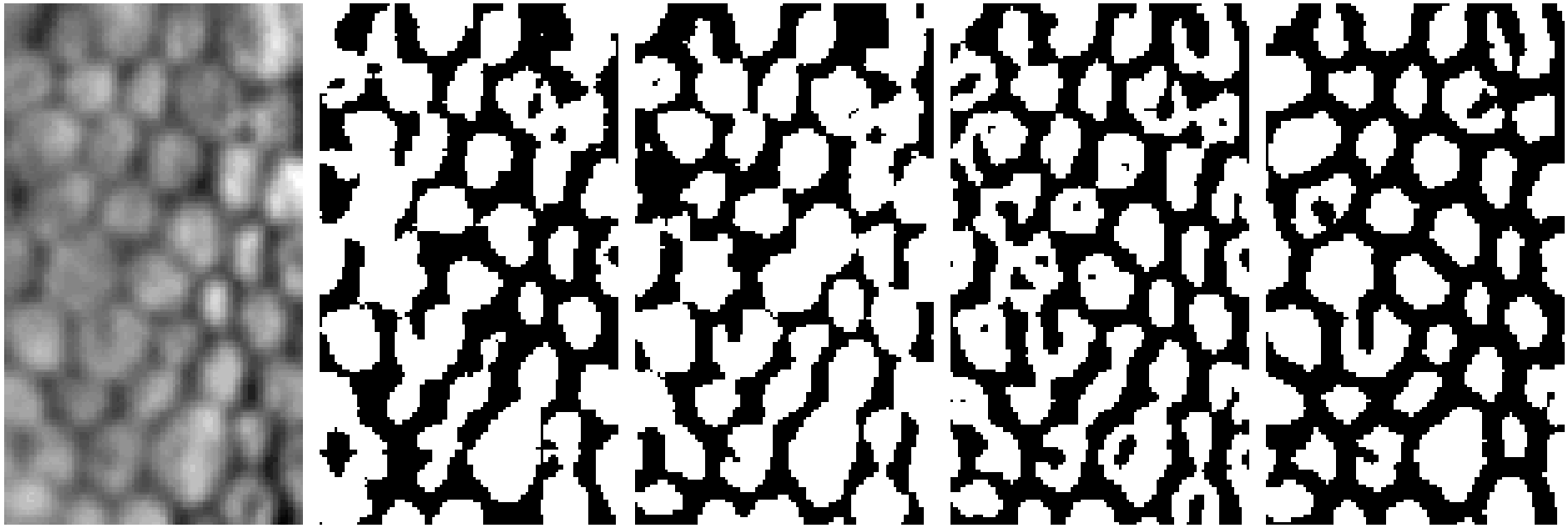
KH Algorithm

… small object removing at the end (40px)

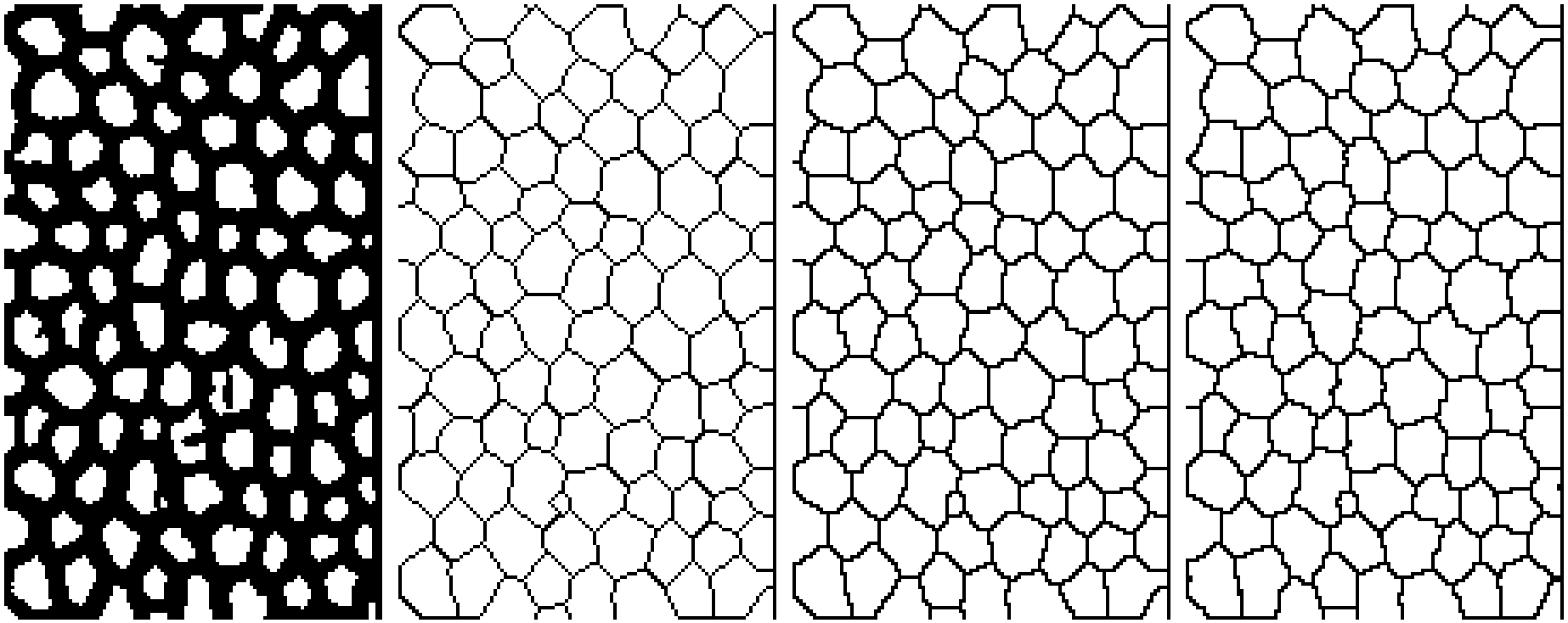


KH Algorithm

org, ench. | adaptive bin | Top-Hat | Single Mask | KH Alg.



THINNING



KH bin,
inverted

thinning
using mask A

thinning
using mask B

thinning
using mask C