Čo ešte...

- Hrany
- Rohy
- Spoje
- Škvrny
- Chrbáty, hrebene (v pohoriach)
- Lokálne príznaky

Hľadanie hrán

skúmame body v okolí (pomocou derivácie)

Ak sa intenzity príliš nelíšia - pravdepodobne tam nie je hrana

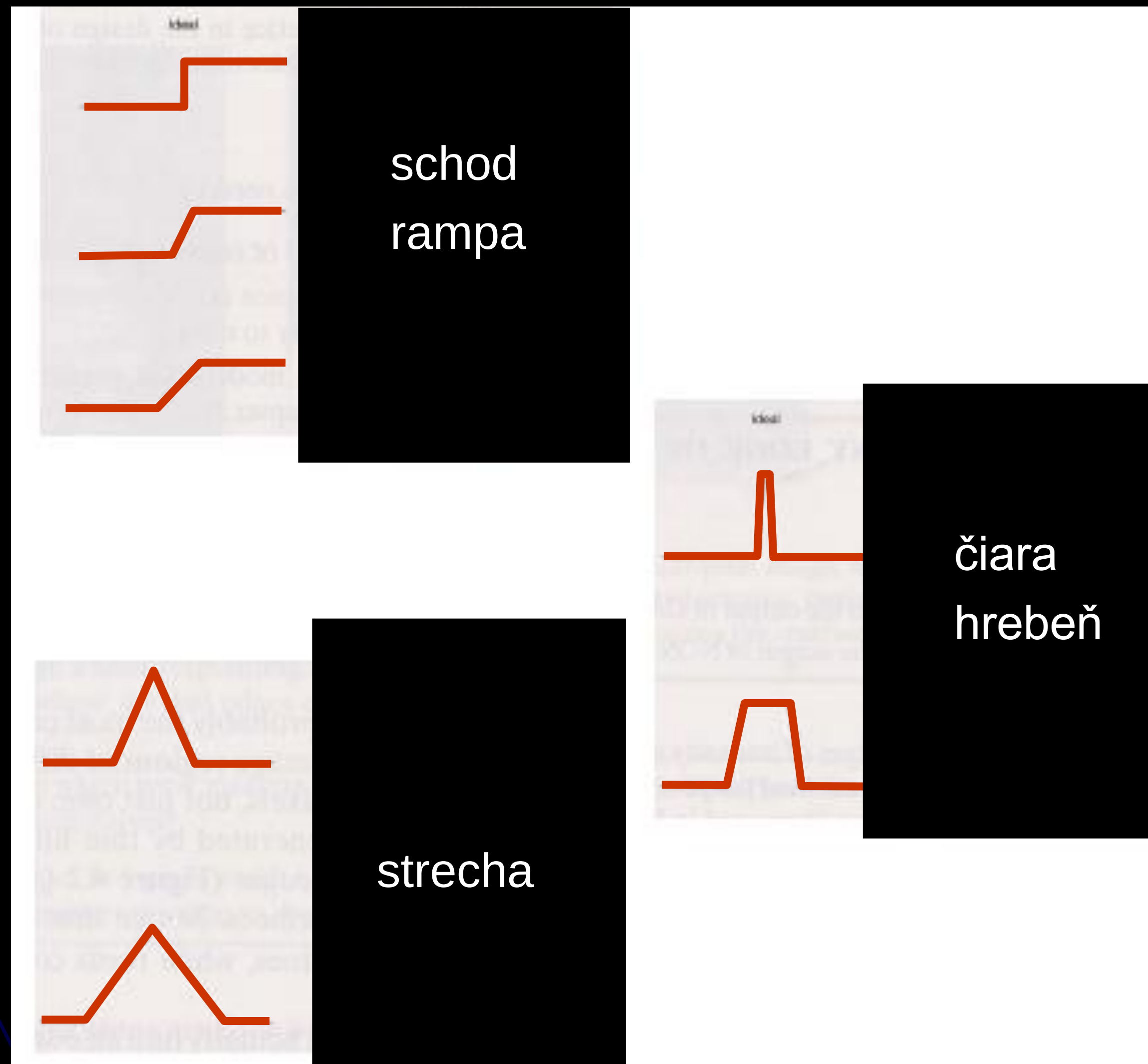
Ak sa líšia - bod môže patriť hrane

Typy hrán

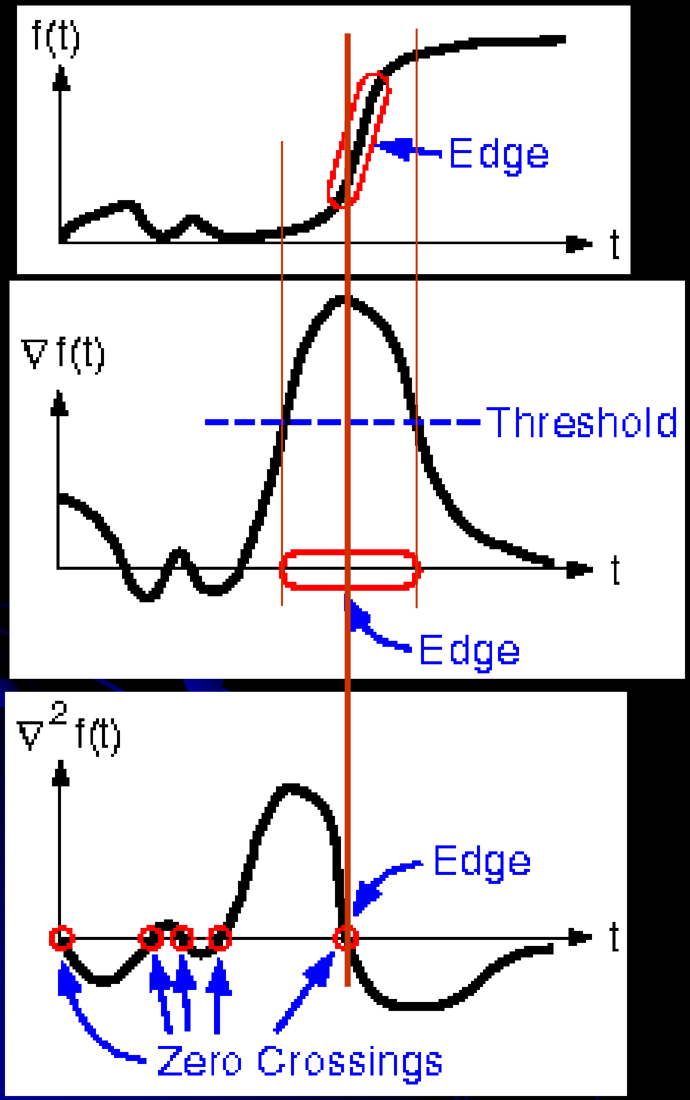
intenzity v reze

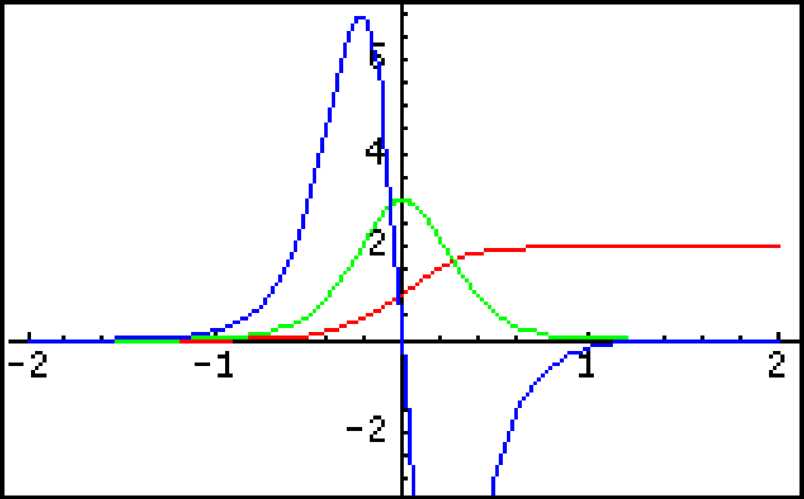
Typy hrán

skutočné hrany - šum



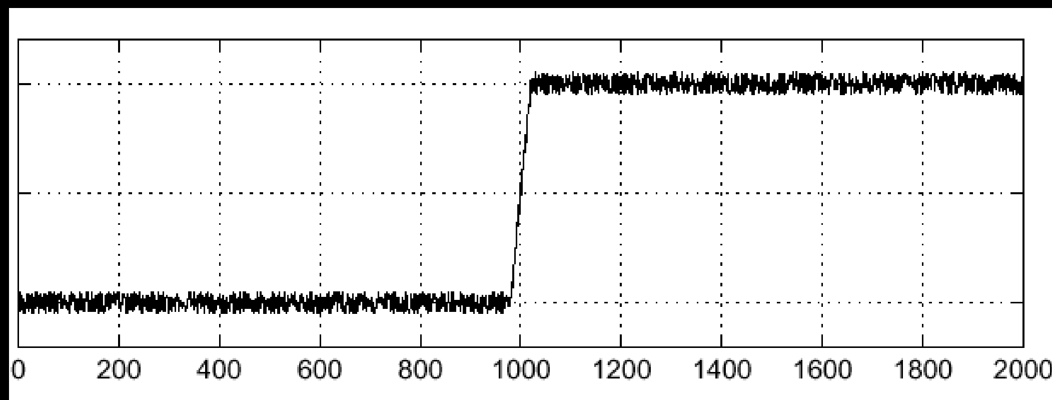
Derivácia


f(t)
Edge
t
∇ f(t)
Threshold
t
Edge
∇2 f(t)
Edge
t
Zero Crossings

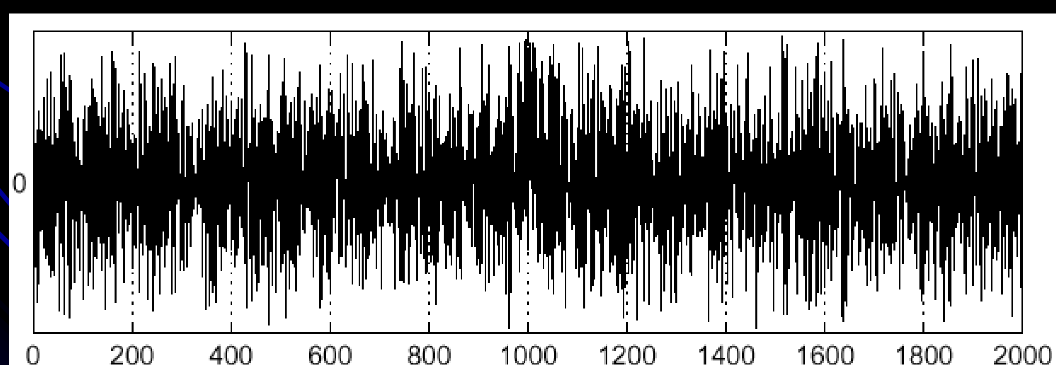

-2
-1
1
2
4
2
-2

Následky šumu

$f(x)$

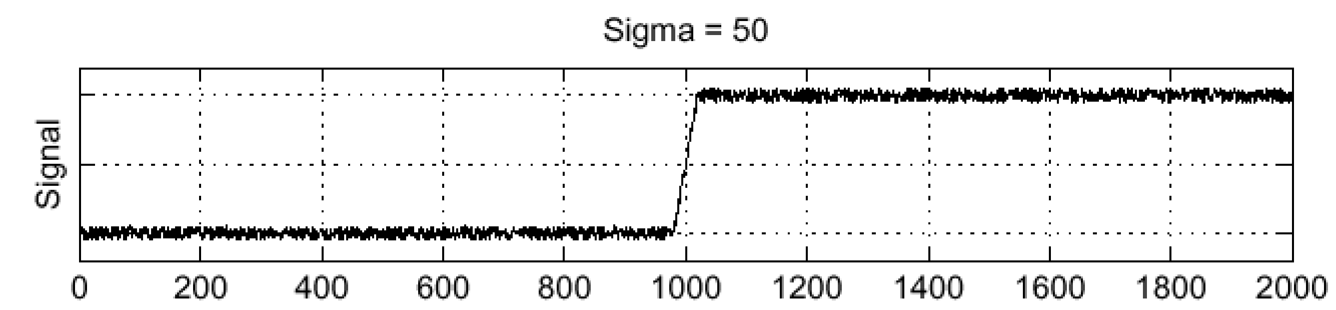


$\frac{d}{dx}f(x)$



Vyhladenie

f



h

$h \star f$

$\frac{\partial}{\partial x}(h \star f)$

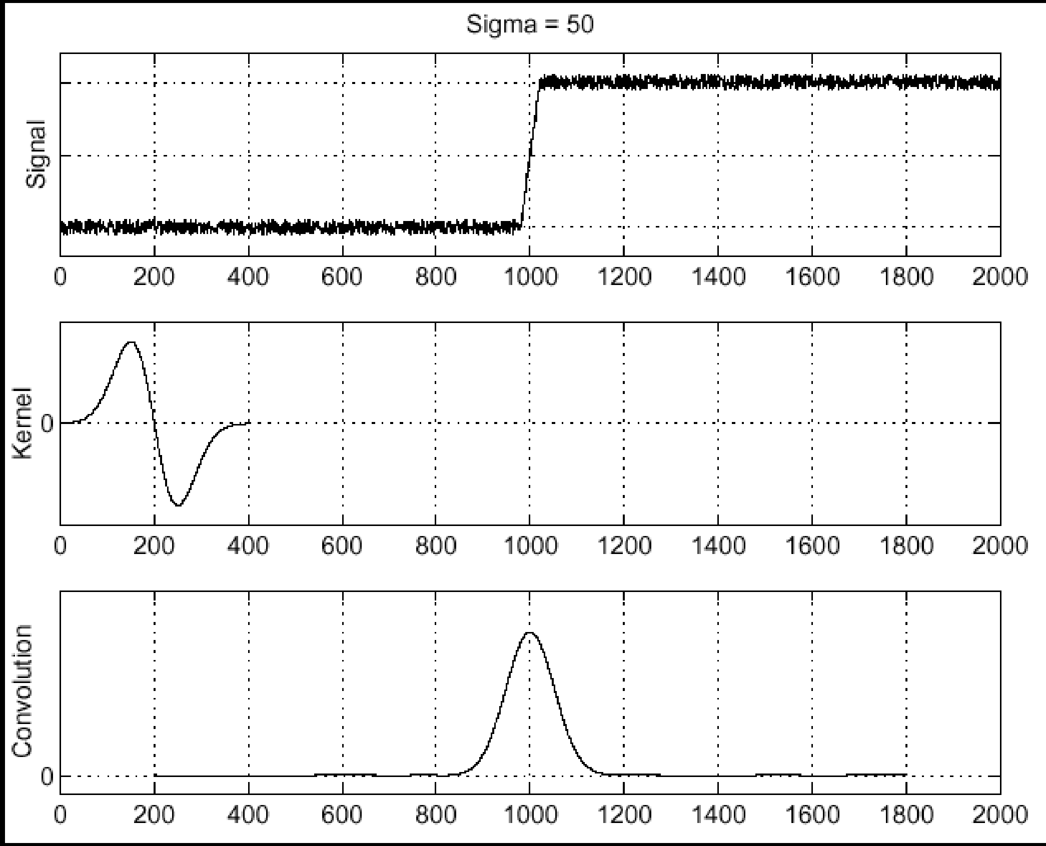
Derivácia konvolúcie

$$\frac{\partial}{\partial x}(h \star f) = (\frac{\partial}{\partial x}h) \star f$$

$$f$$

$$\frac{\partial}{\partial x}h$$

$$(\frac{\partial}{\partial x}h) \star f$$



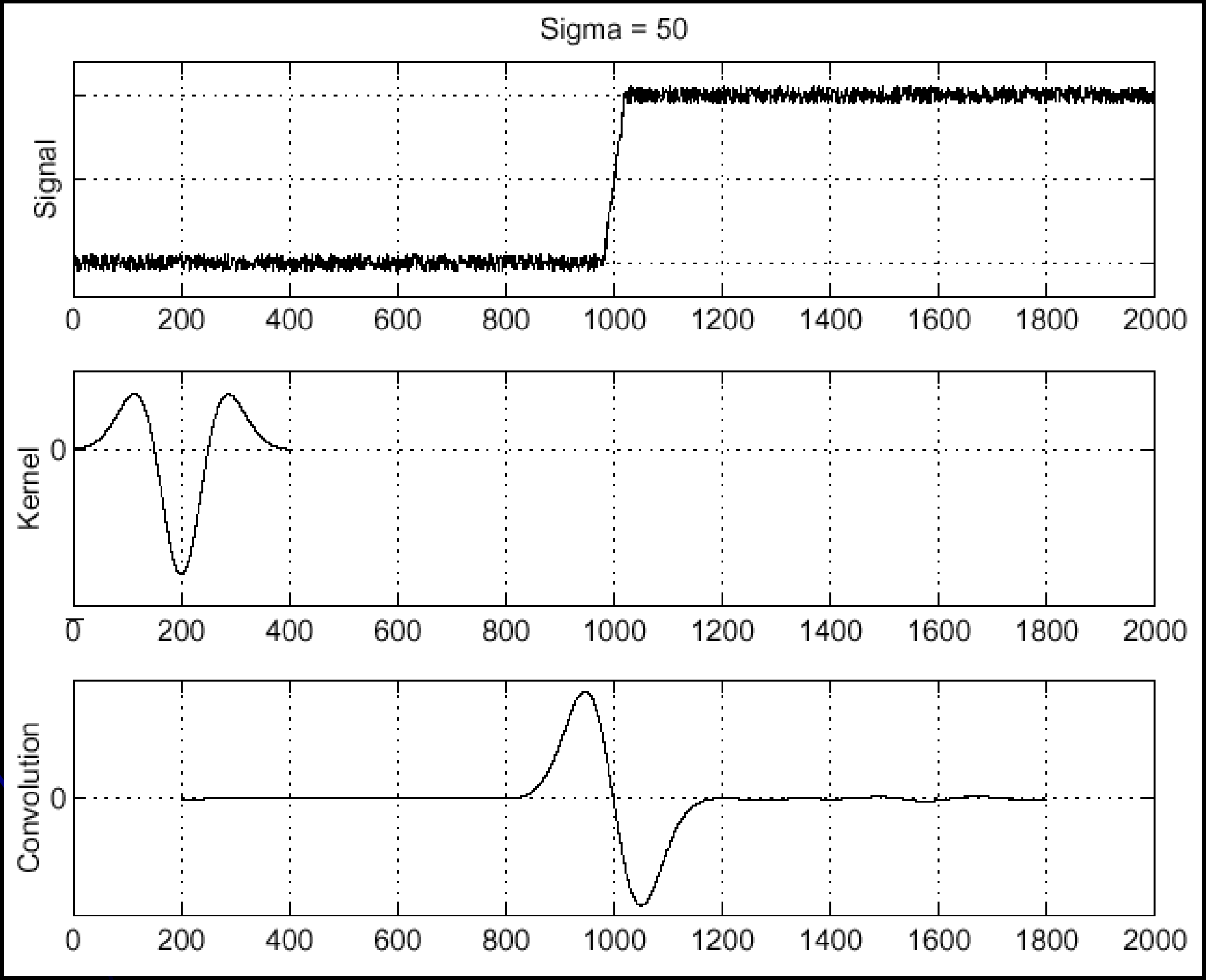
Laplacián Gaussiánu

$$\frac{\partial^2}{\partial x^2}(h \star f)$$

$$f$$

$$\frac{\partial^2}{\partial x^2}h$$

$$(\frac{\partial^2}{\partial x^2}h) \star f$$

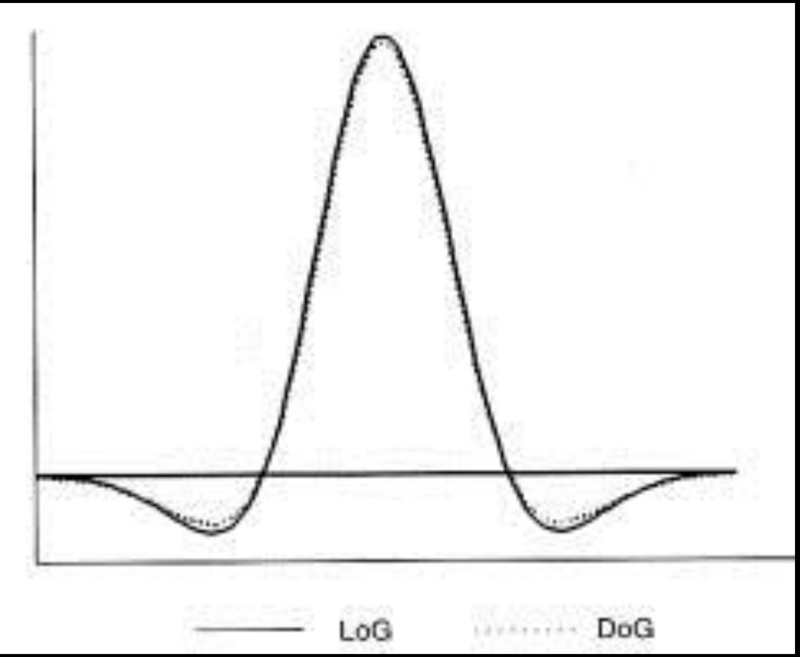


Rozdiel Gaussiánov

Aproximácia LoG operátora – DoG

Rozdiel Gaussiánov s dostatočne rozdielnymi σ

$\sigma_1 / \sigma_2 = 1.6$



LoG ($\sigma = 12.35$)
DoG ($\sigma_1 = 10$, $\sigma_2 = 16$)

Sobel

$$I \otimes \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix} \longrightarrow \frac{d}{dx} I$$

$$I \otimes \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \longrightarrow \frac{d}{dy} I$$

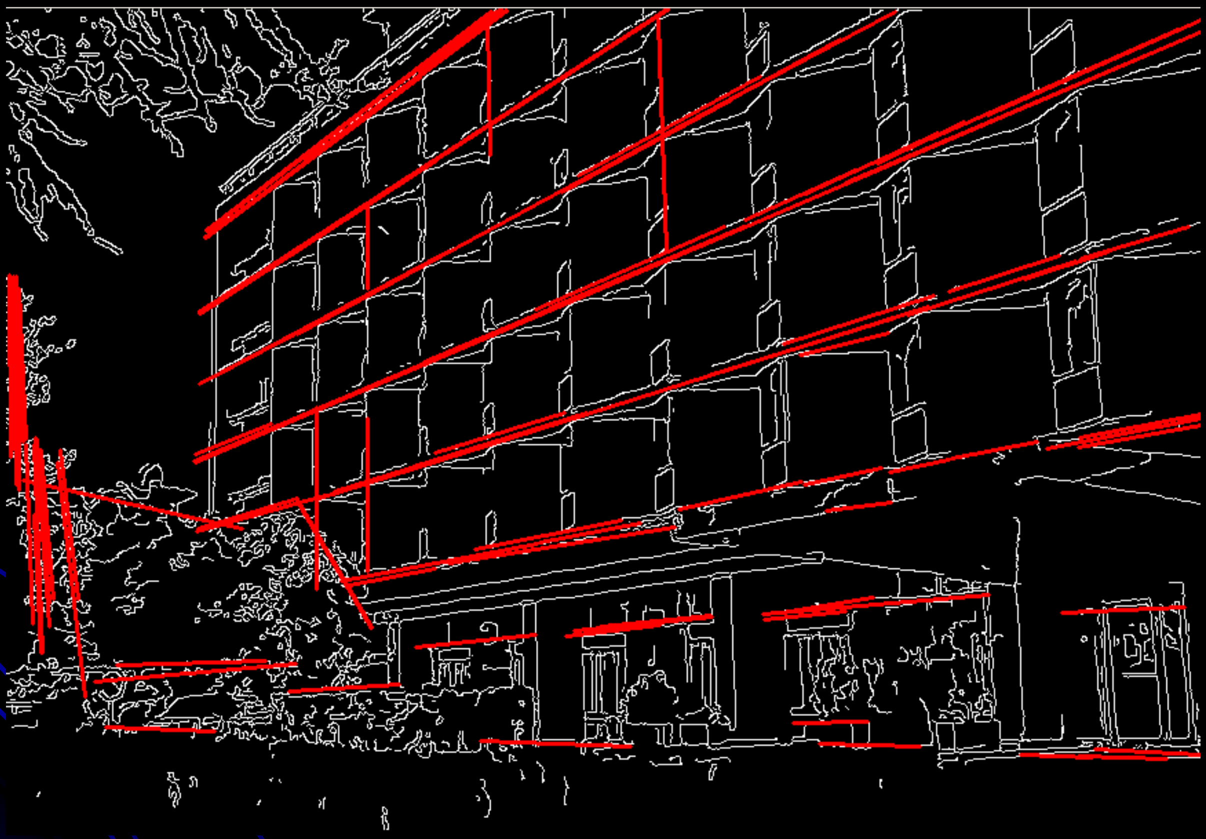
$$\sqrt{\left(\frac{d}{dx} I\right)^2 + \left(\frac{d}{dy} I\right)^2}$$

$\downarrow$

prahovanie

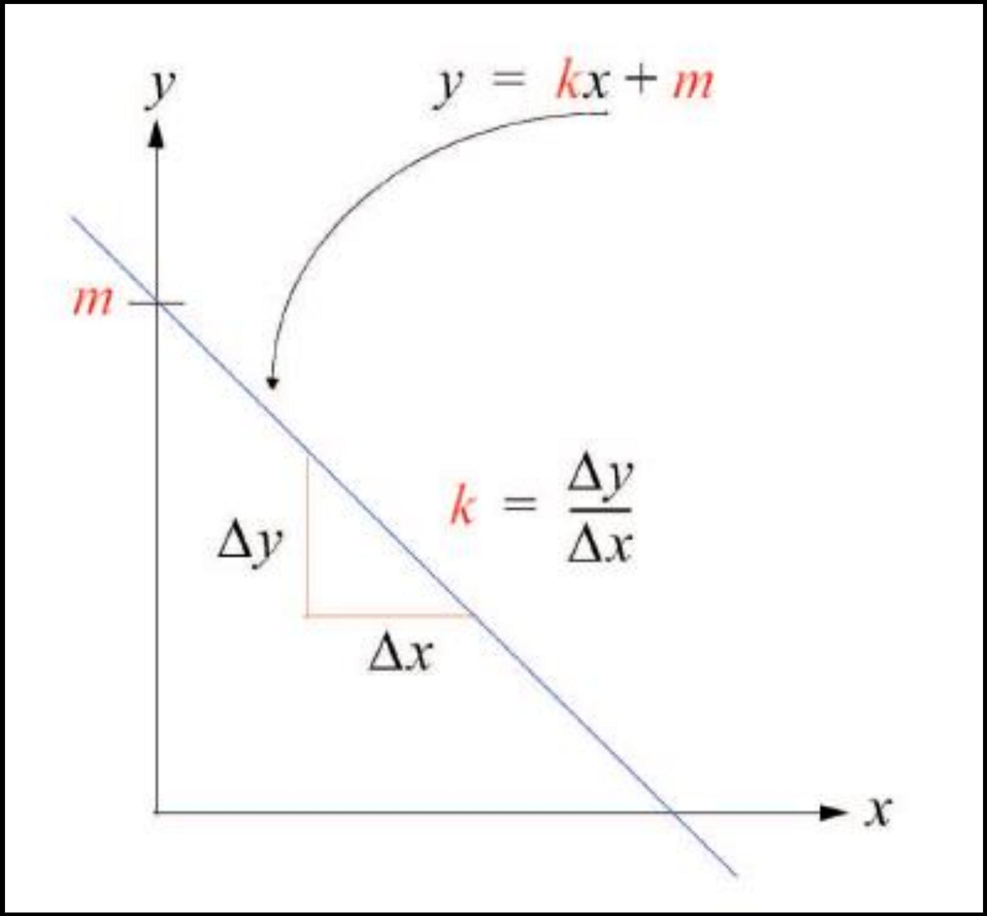
$\downarrow$

hrany



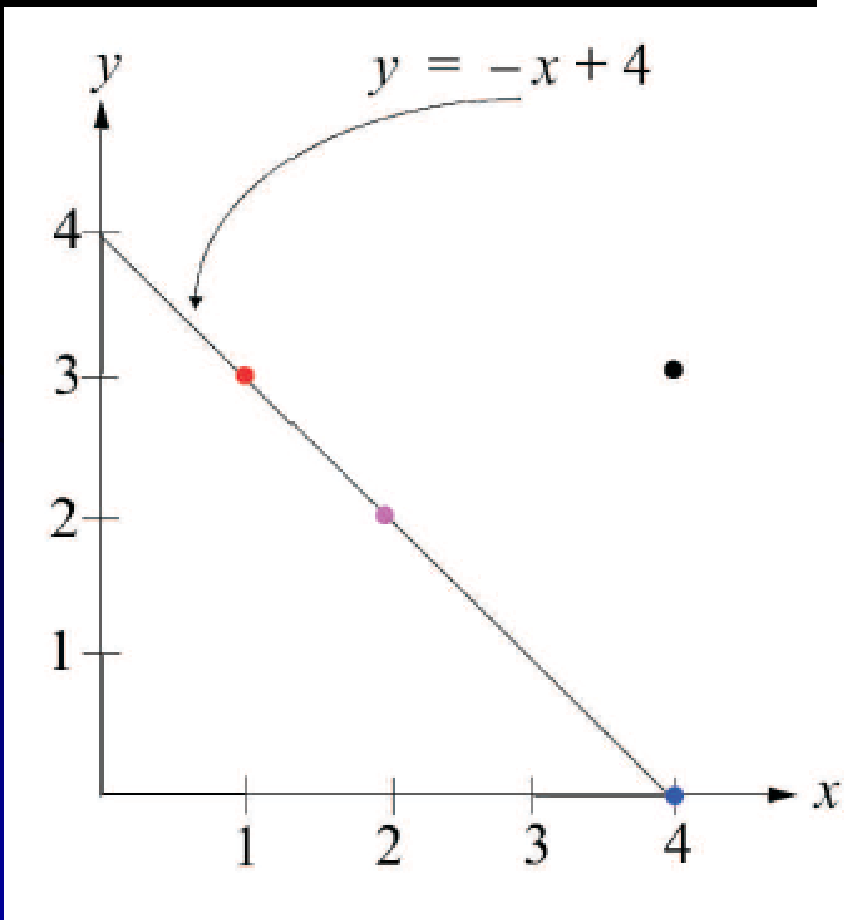
Houghova transformácia

$y = kx + m$

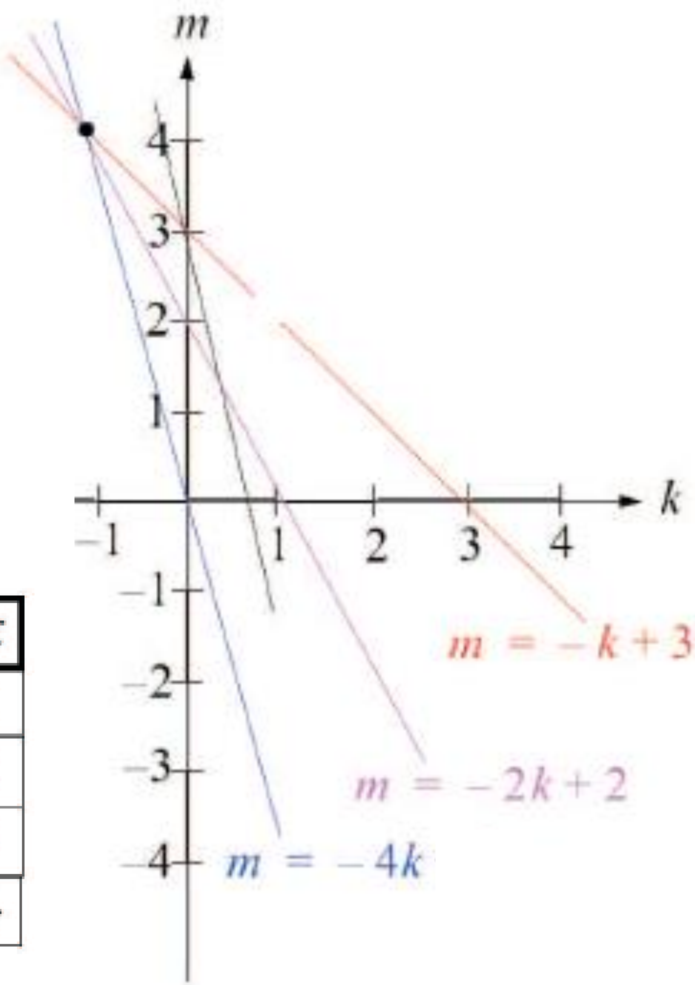


$m = -xk + y$

Problém?

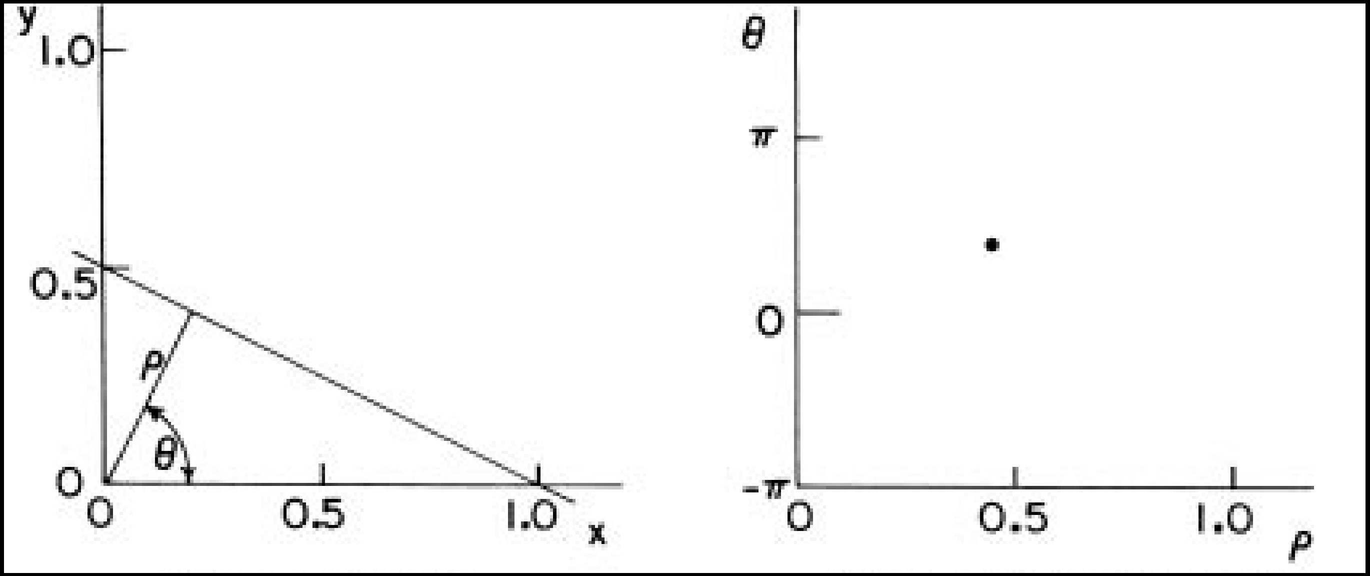


y	x
3	1
2	2
0	4
3	4

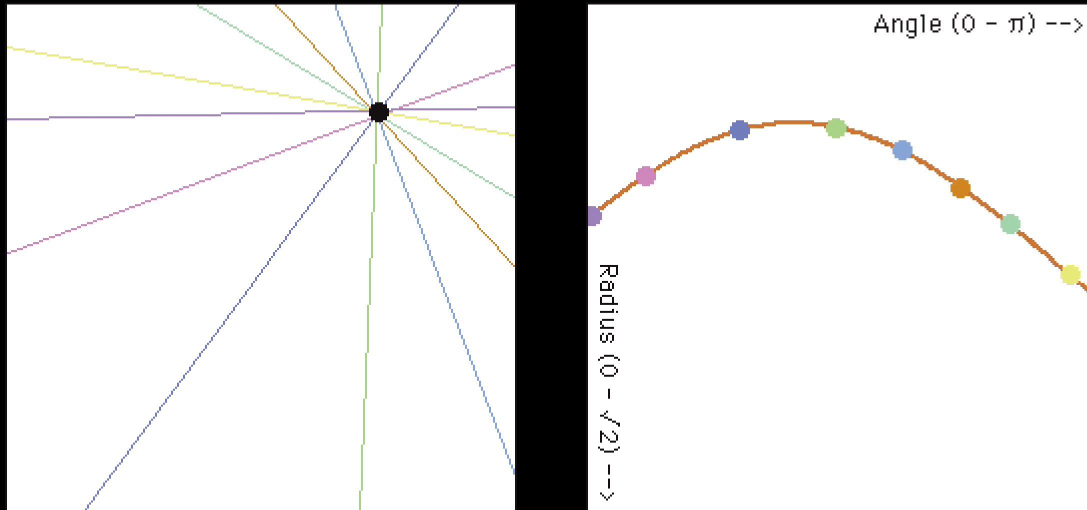


Houghova transformácia

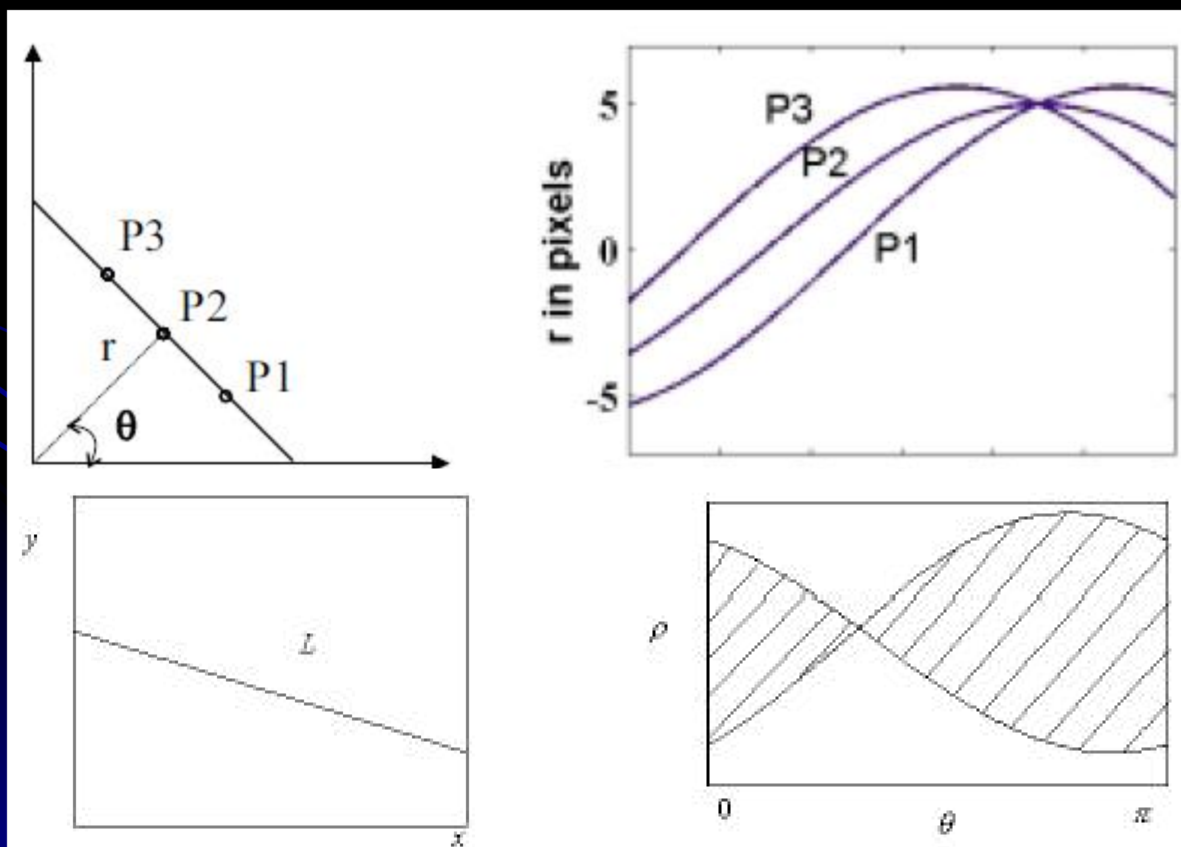
$y = m \cdot x + b$

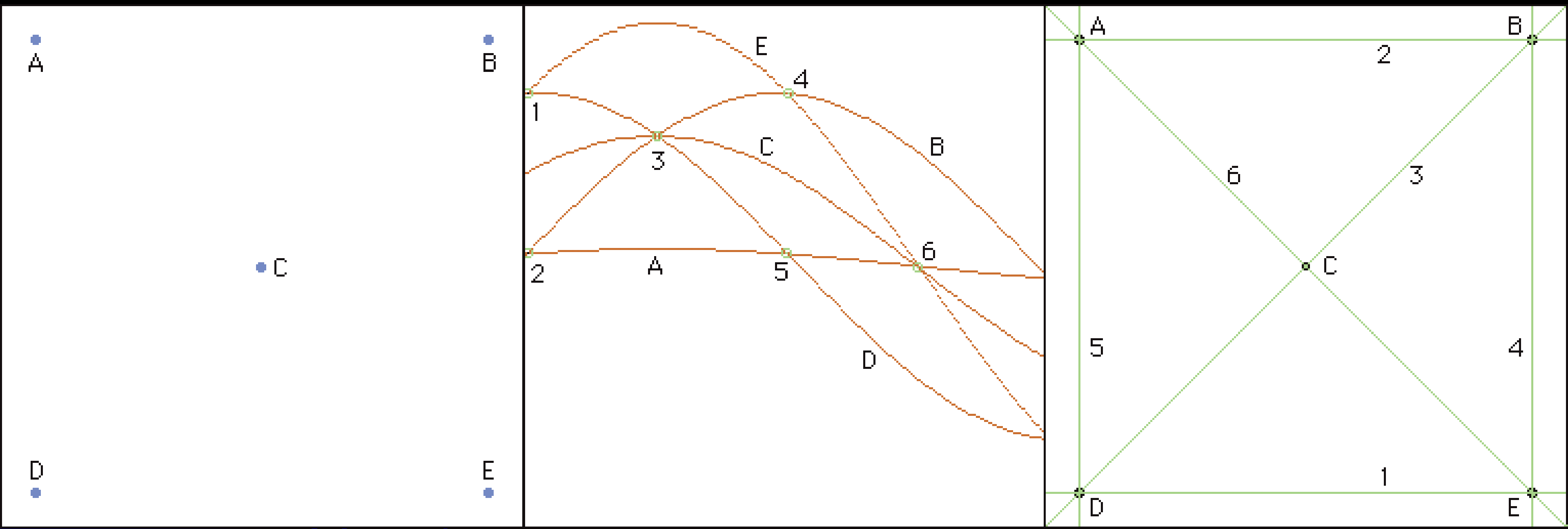


$\rho = x \cos \theta + y \sin \theta$



$$\rho = x \cos \theta + y \sin \theta$$




A
B
C
D
E
E
4
1
3
C
B
2
A
5
6
D
A
B
2
6
3
C
5
4
1
D
E

Houghova transformácia

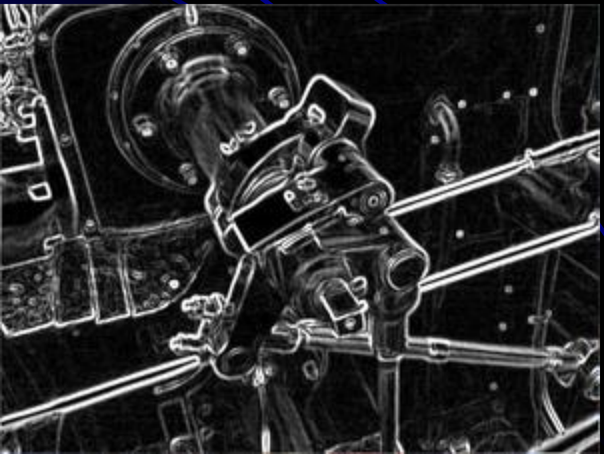
Algoritmus

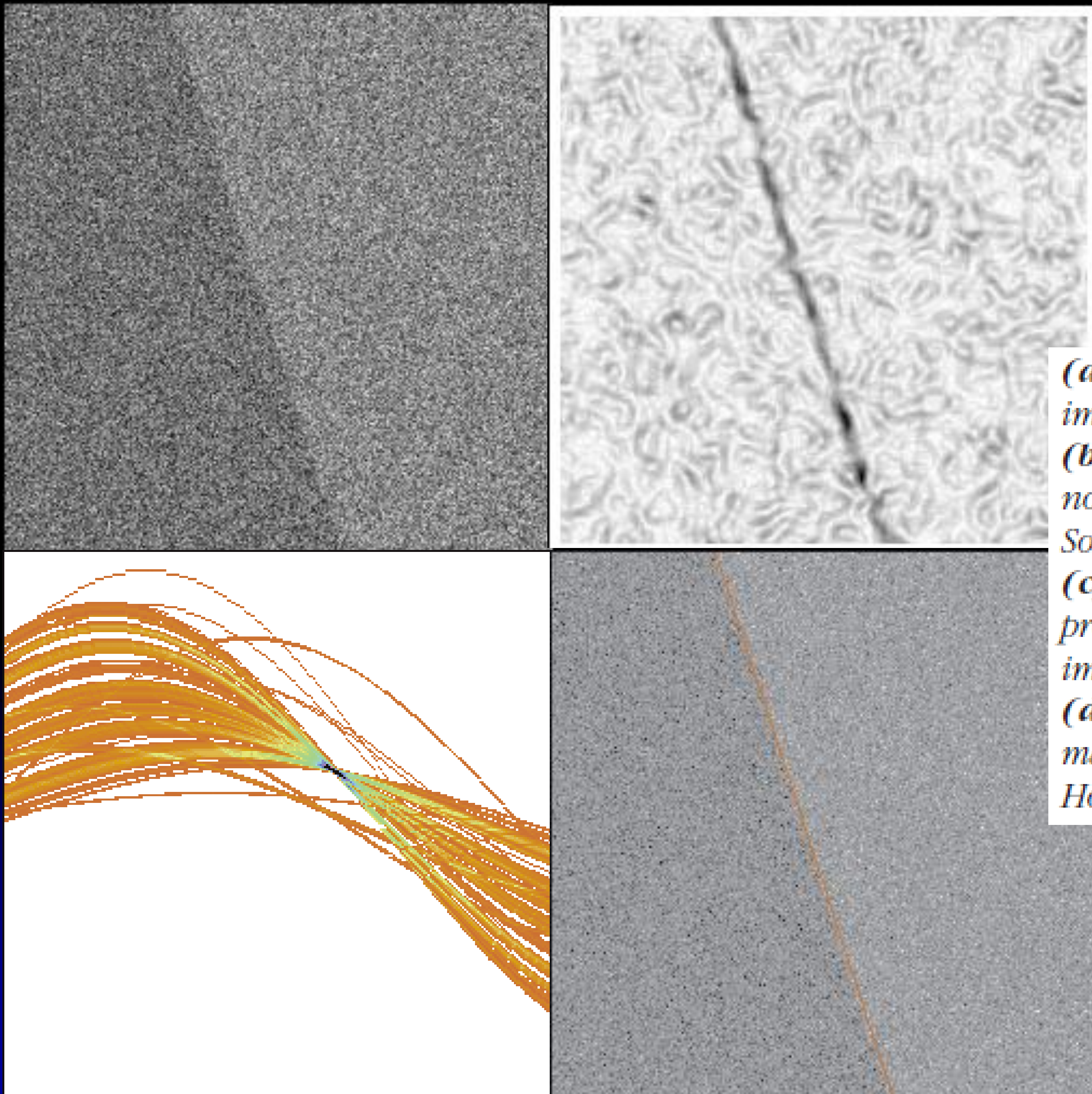
1. Kvantizácia parametrického priestoru (θ na 360 stupňov, ρ na polovičnú dĺžku diagonály, (0,0) je v stredu obrazu)
2. Každý bod parametrického priestoru je akumulátorom, začína hodnotou 0
3. Pre každý bod hrany (x,y), zvýš hodnotu akumulátora
4. Nájdi maximá v parametrickom priestore, určujú priamky v obraze

Maximá

Hľadáme lokálne maximá, nie N najvyšších hodnôt

- nájdeme akumulátor, ktorý má maximálnu hodnotu
- určíme zodpovedajúcu priamku
- potlačíme hodnoty v okolí akumulátora
- opakujeme N krát





(a) *the original noisy image;*
(b) *smoothing to reduce the noise and application of a Sobel gradient filter;*
(c) *Hough transform produced from the gradient image;*
(d) *line defined by the maximum point in the Hough transform.*

Všeobecná Houghova transformácia

Ľubovoľná analytická krivka v tvare f(**x**,**a**)=0

x – obrazový bod

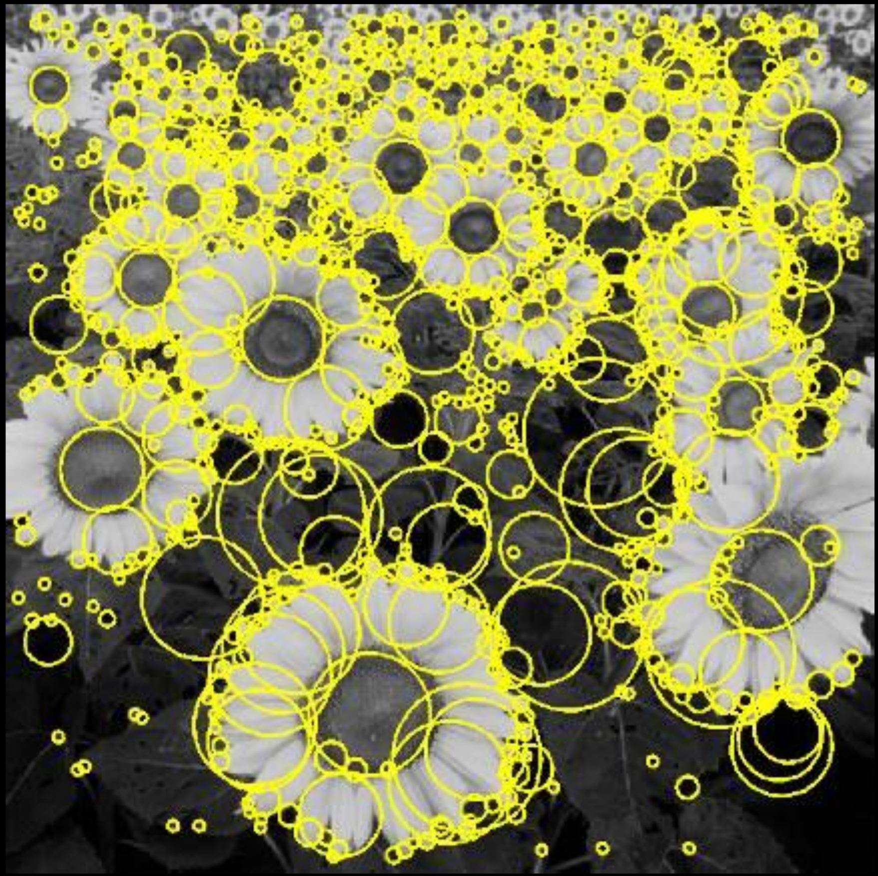
a – vektor parametrov

A(**a**) - parametrický priestor

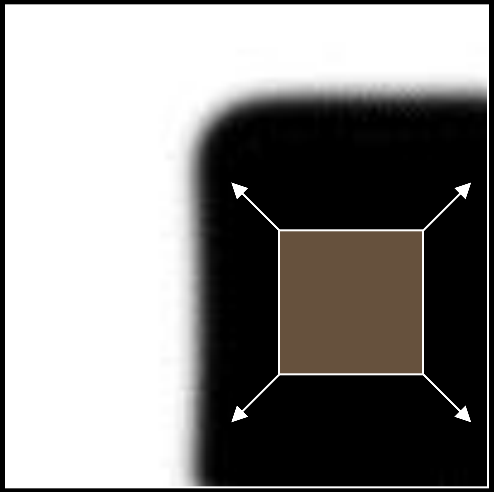
Pre každý bod (x,y), zvyšujeme hodnotu akumulátora **a**, ktorý spĺňa f(**x**,**a**)=0

Maximá v parametrickom priestore určujú krivky v obraze

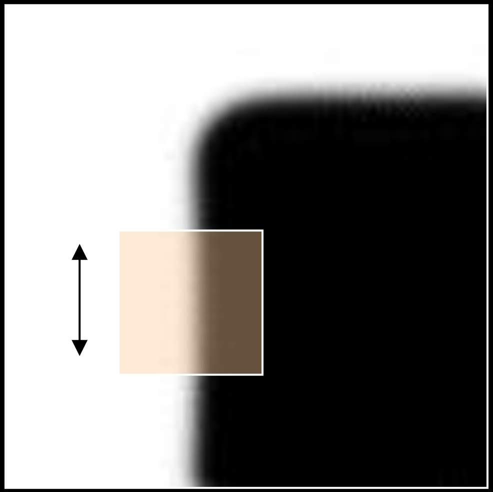
Rohy a škvrny



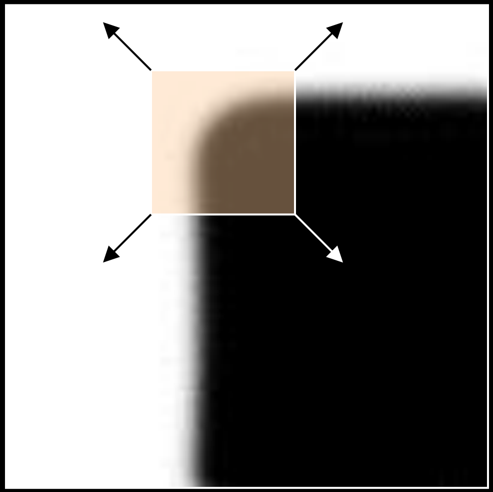
Rohový bod



“hladký” región: bez zmeny v každom smere



“hrana”: bez zmeny v smere hrany



“roh”: zmena vo všetkých smeroch

Moravcov detektor rohov

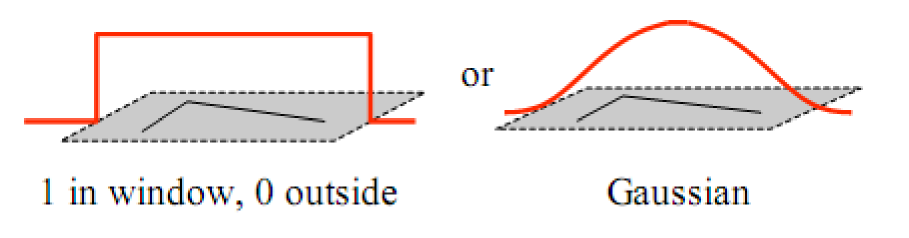
Body s nízkou sebepodobnosťou

Testujeme každé okno, či sa podobá na okolité okná

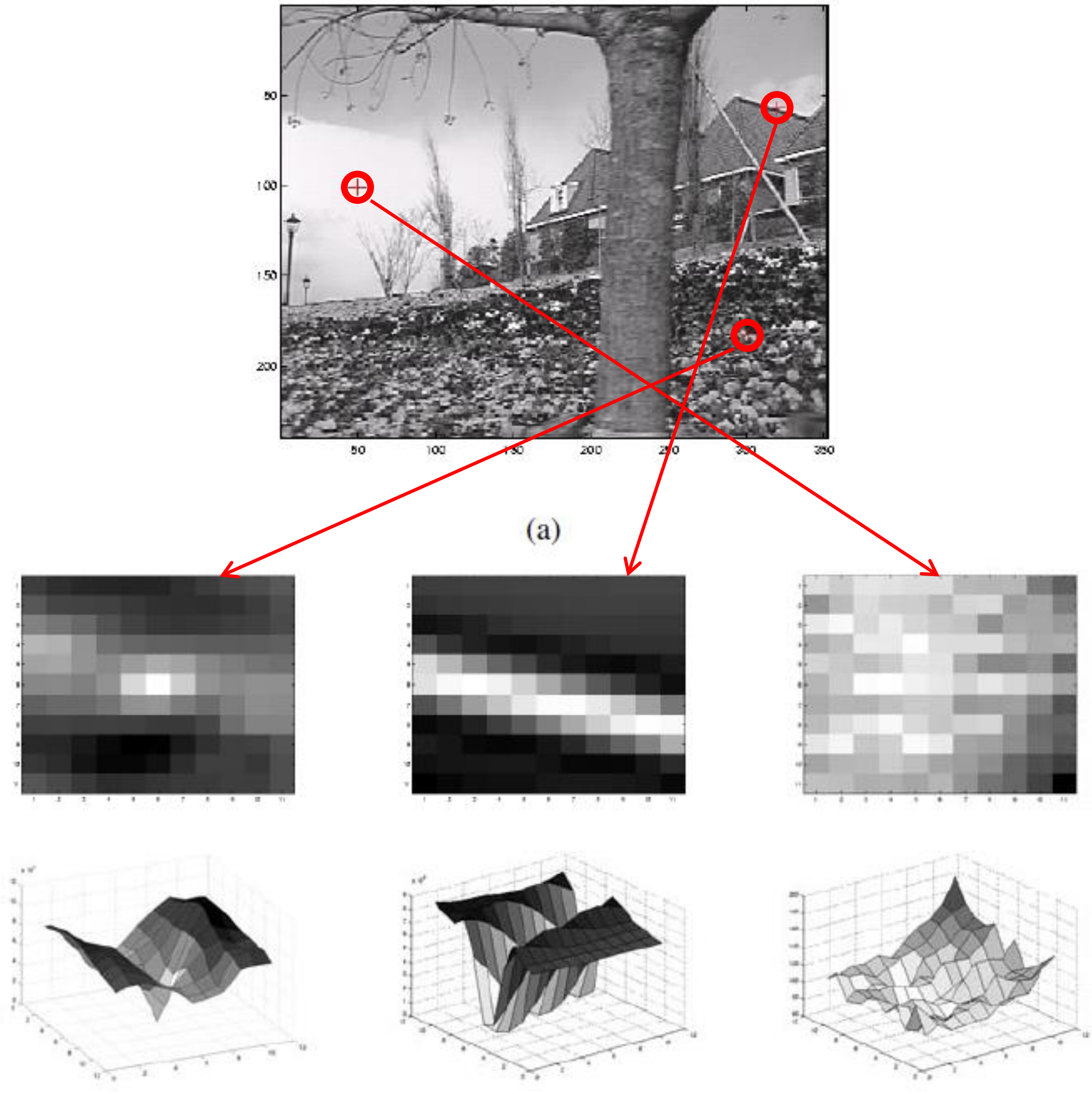
Vážená suma štvorcov rozdielov medzi oknami:

$$E_{WSSD}(\mathbf{u}) = \sum_i w(\mathbf{p_i})(I(\mathbf{p_i} + \mathbf{u}) - I(\mathbf{p_i}))^2$$

u = (u; v) – vektor posunutia
w(x) – váhová funkcia
i – určuje pixel okna



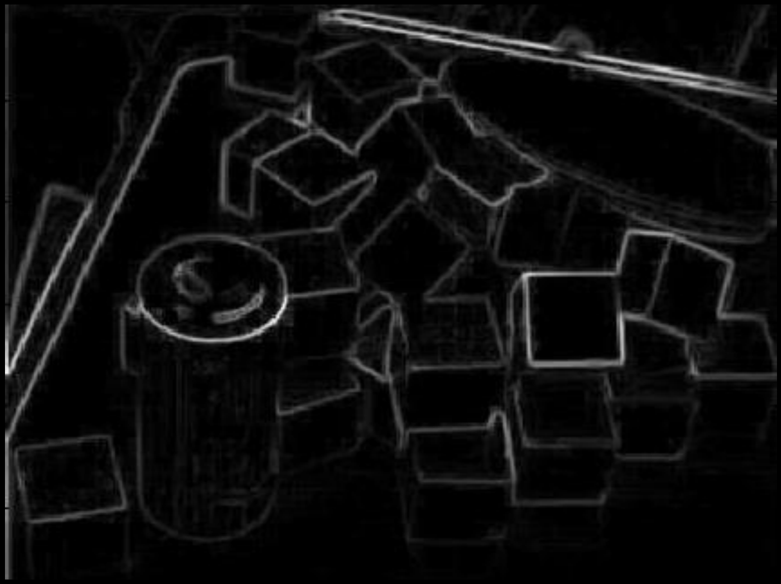
Rohovitosť bodu je daná najmenšou hodnotou E medzi oknami určenými bodom a jeho 8 susedmi



(a)

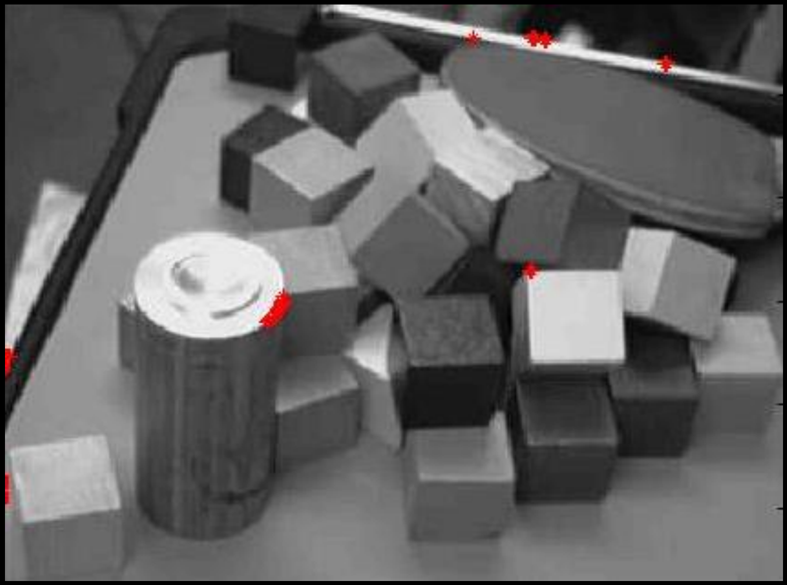
(b) (c) (d)

$I(x, y)$



E_{WSSD}

$$E_{WSSD} > 50$$



$$E_{WSSD} > 65$$

Vylepšenie - Harris

$$E_{WSSD}(\mathbf{u}) = \sum_i w(\mathbf{p_i})\left[\boxed{I(\mathbf{p_i} + \mathbf{u})} - I(\mathbf{p_i})\right]^2$$

Taylor

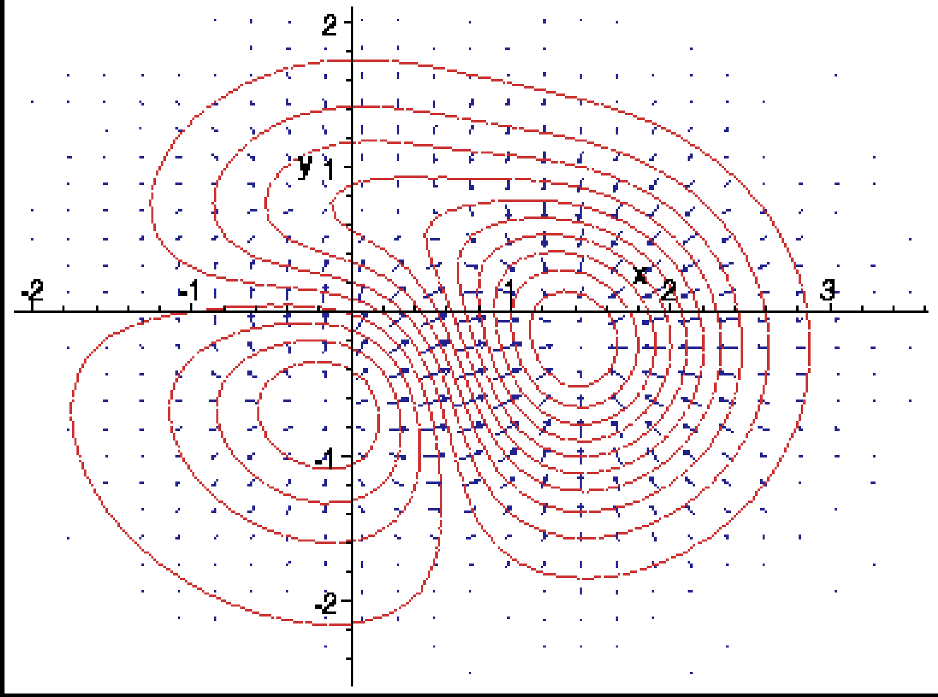
$$\approx \sum_i w(\mathbf{p_i})\left[\boxed{I(\mathbf{p_i}) + \nabla I(\mathbf{p_i}).\mathbf{u}} - I(\mathbf{p_i})\right]^2$$

$$= \sum_i w(\mathbf{p_i})\left[\nabla I(\mathbf{p_i}).\mathbf{u}\right]^2$$

$$= \mathbf{u}^T \mathbf{A}\mathbf{u}$$

$$A = \sum_{x,y} w(x,y) \begin{bmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{bmatrix}$$

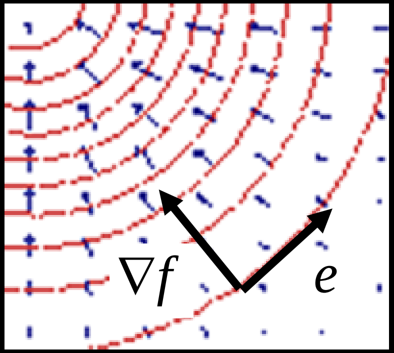
Gradient



Gradient:

$$\nabla f = \left[\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y}\right]$$

Smer – najväčšia zmena intenzity



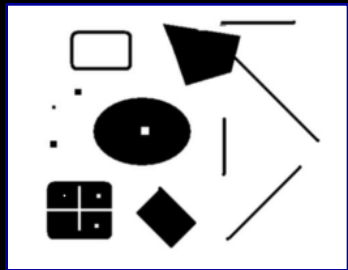
Smer gradientu: $$\theta = \tan^{-1}\left(\frac{\partial f}{\partial y} / \frac{\partial f}{\partial x}\right)$$

Veľkosť gradientu: $$\|\nabla f\| = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2}$$

Harrisov detektor rohov

1. Derivácia intenzity obrazu v smere x a y
2. Matica M $= \begin{bmatrix} \sum I_x I_x & \sum I_x I_y \\ \sum I_x I_y & \sum I_y I_y \end{bmatrix} = \sum \begin{bmatrix} I_x \\ I_y \end{bmatrix} [I_x \ I_y] = \sum \nabla I (\nabla I)^T$
3. Gaussov filter na M

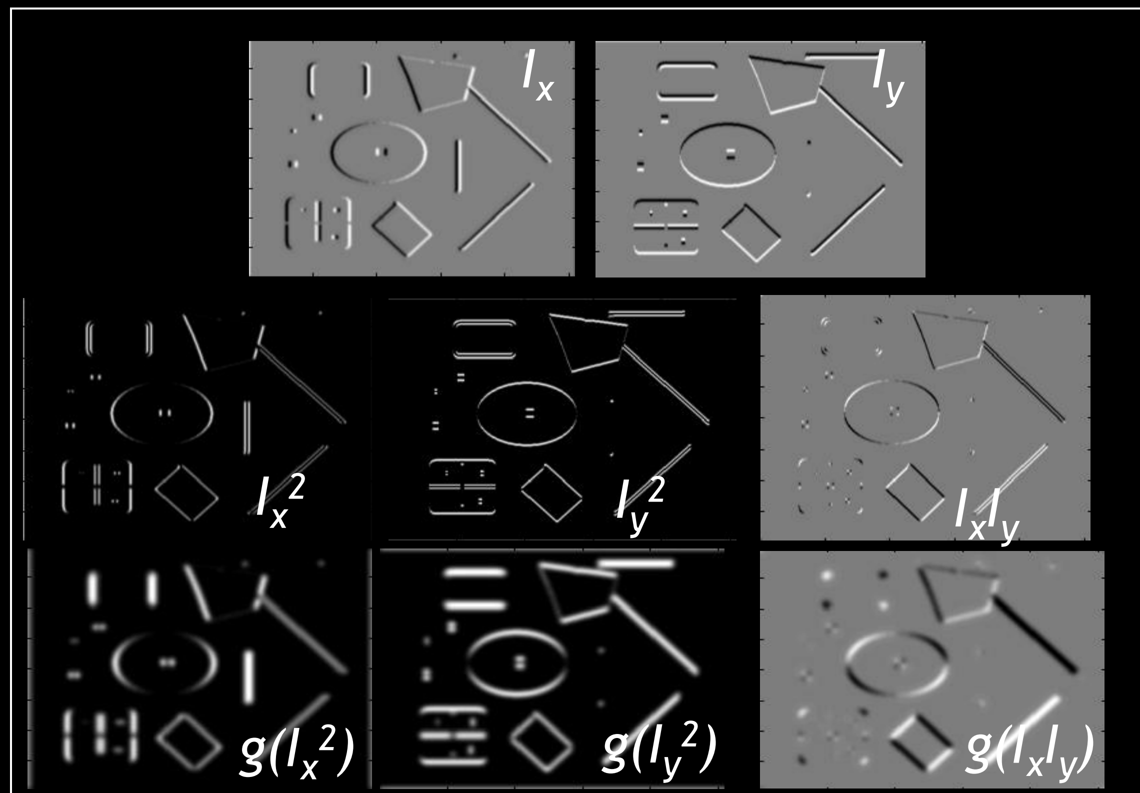
$$A = \sum_{x,y} w(x,y) \begin{bmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{bmatrix}$$



Derivácie obrazu

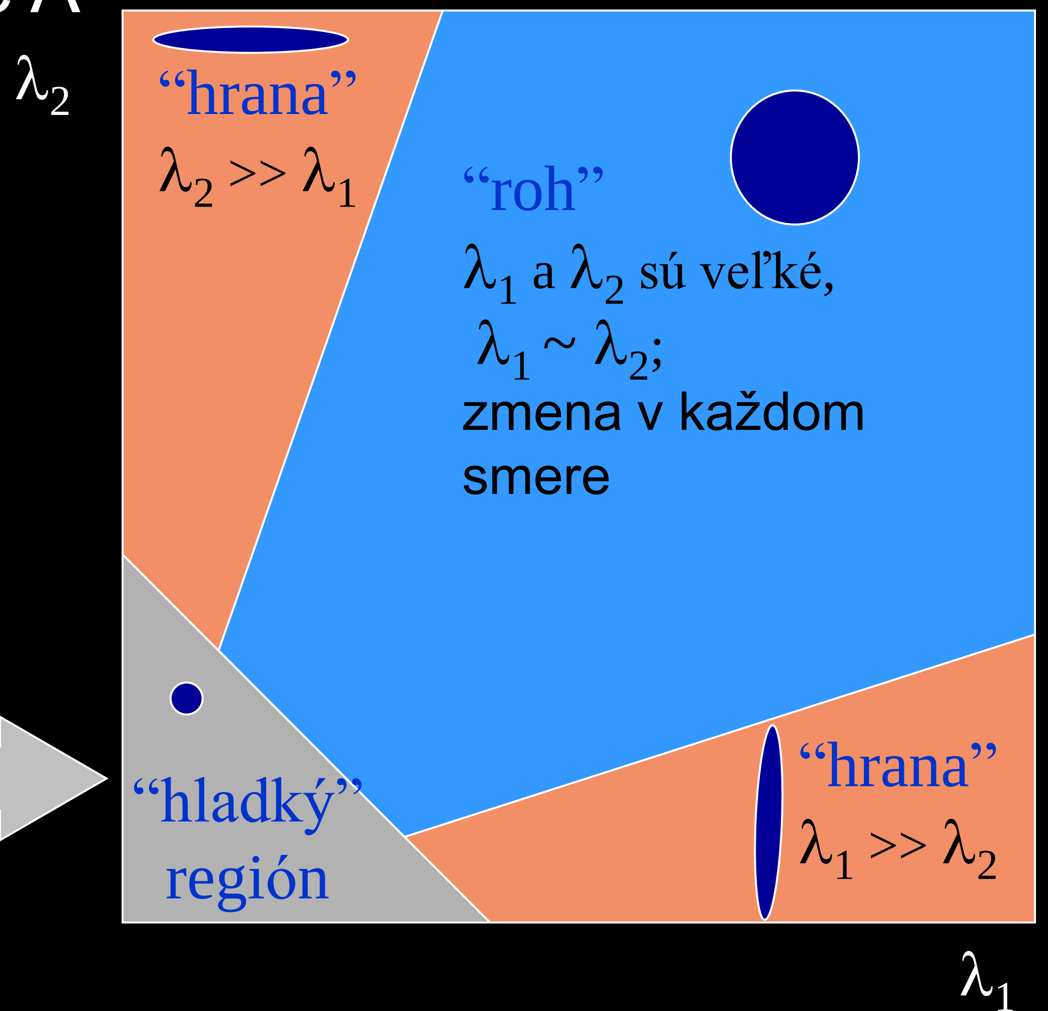
Násobenie derivácií

Gaussov filter



Charakteristika matice A

Vlastné čísla matice A



λ_1 a λ_2 sú malé;
bez zmeny v žiadnom smere

Harrisov detektor rohov

4. Funkcia *R*

$$R = \det(M) - \alpha\, \mathrm{trace}(M)^2$$

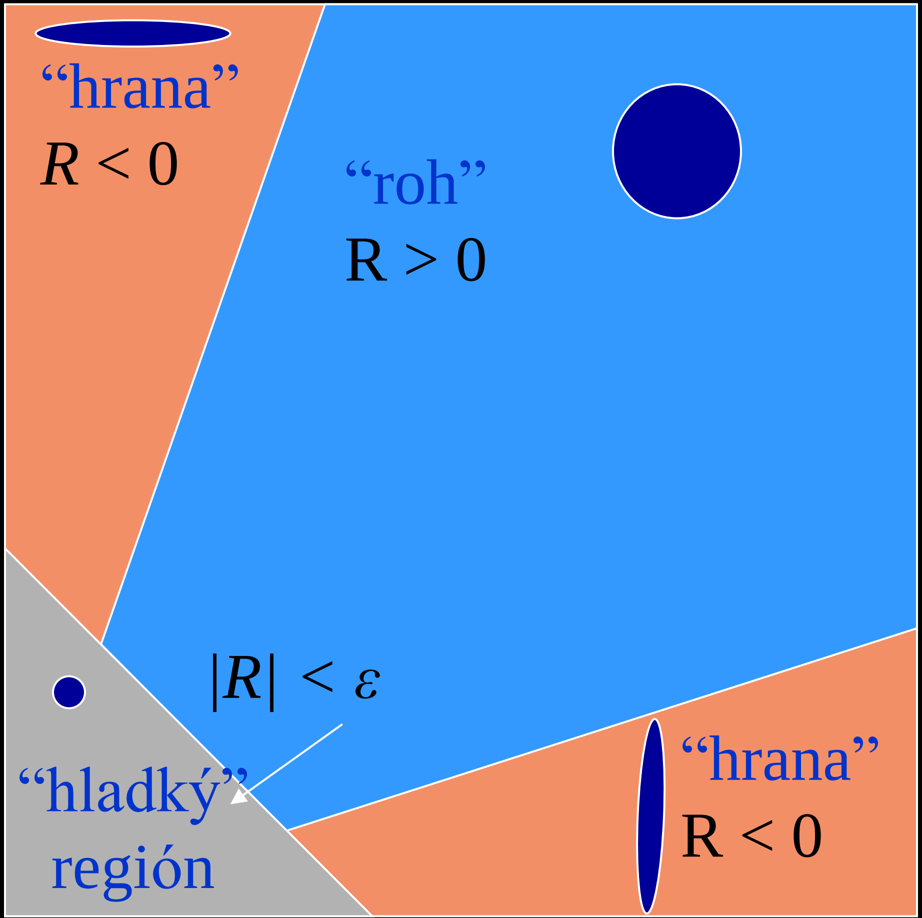
$$\det(M) = \lambda_1 \lambda_2$$
$$\mathrm{trace}(M) = \lambda_1 + \lambda_2$$

5. prahovanie *R*
6. Lokálne maximá R (potlačenie nemaximálnych bodov)

(α – empirická konštanta, α = 0.04-0.06)

Funkcia R

$$R = \det(M) - \alpha\, \mathrm{trace}(M)^2 = \lambda_1\lambda_2 - \alpha(\lambda_1 + \lambda_2)^2$$



Iné funkcie odozvy

1. Harris and Stephens (1988)

$$\det(A) - \alpha \operatorname{trace}(A)^2 = \lambda_0\lambda_1 - \alpha(\lambda_0 + \lambda_1)^2$$

2. Shi and Tomasi (1994)

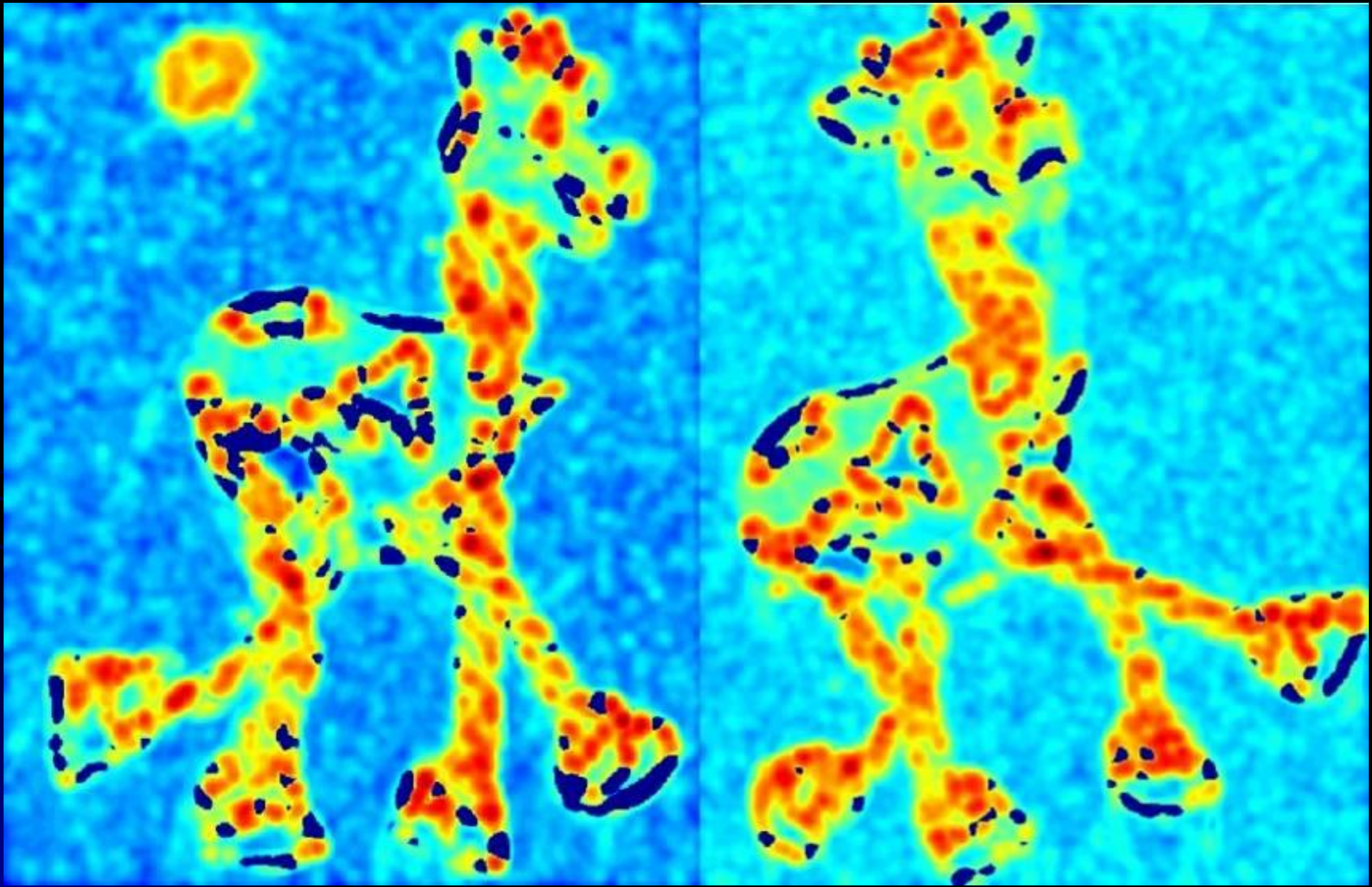
   Najmenšie vlastné číslo

3. Triggs (2004)

$$\lambda_0 - \alpha\lambda_1$$ $(\alpha = 0.05)$

4. Brown, Szeliski, and Winder (2005)

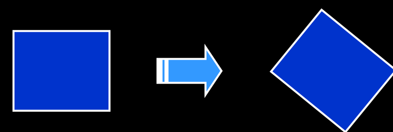
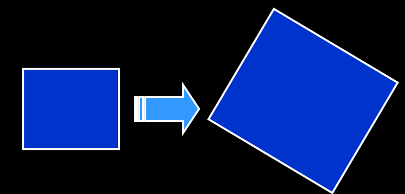
$$\frac{\det A}{\operatorname{tr} A} = \frac{\lambda_0\lambda_1}{\lambda_0 + \lambda_1}$$



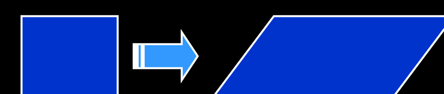
$$\begin{matrix} S_\sigma(R_x^2 + G_x^2 + B_x^2) & S_\sigma(R_x R_y + G_x G_y + B_x B_y) \\ S_\sigma(R_x R_y + G_x G_y + B_x B_y) & S_\sigma(R_y^2 + G_y^2 + B_y^2) \end{matrix}$$

Obrazové zmeny

Geometrické

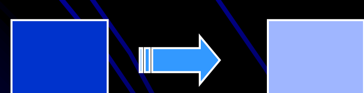
otočenie  

podobnosť (otočenie + rovnomerné škálovanie)

Afinné (nerovnomerné škálovanie) 

Fotometrické

Škálovanie intenzity ($I \rightarrow a\,I + b$)

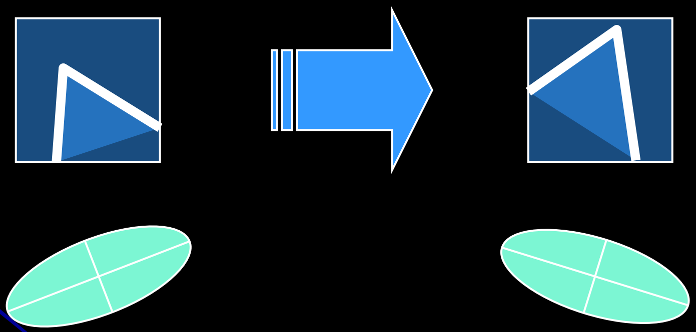


Harris

Zmena intenzity I' = a I + b

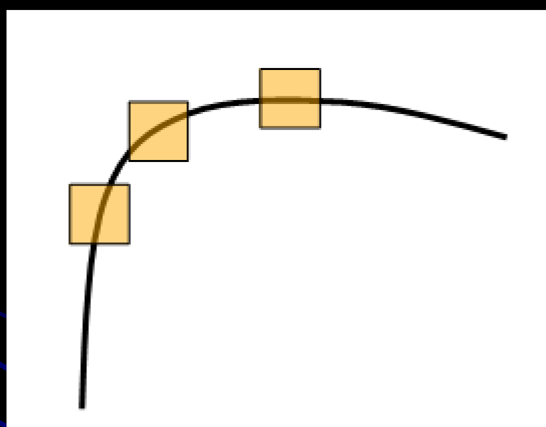
používame derivácie

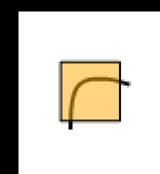
otočenie



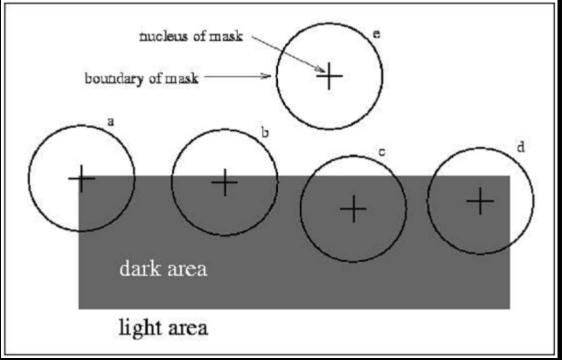
Vlastné čísla nezávisia od orientácie

škálovanie?

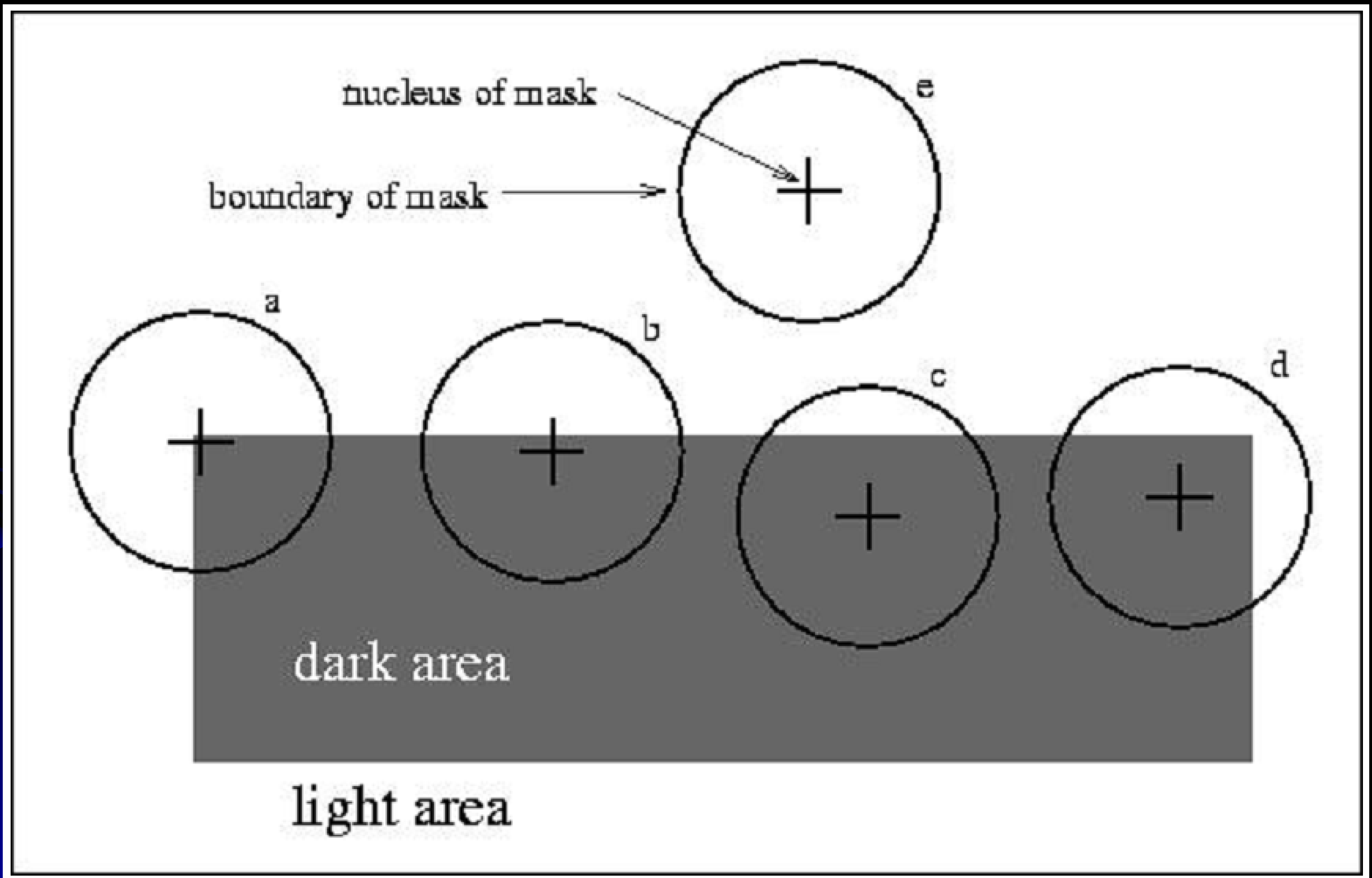


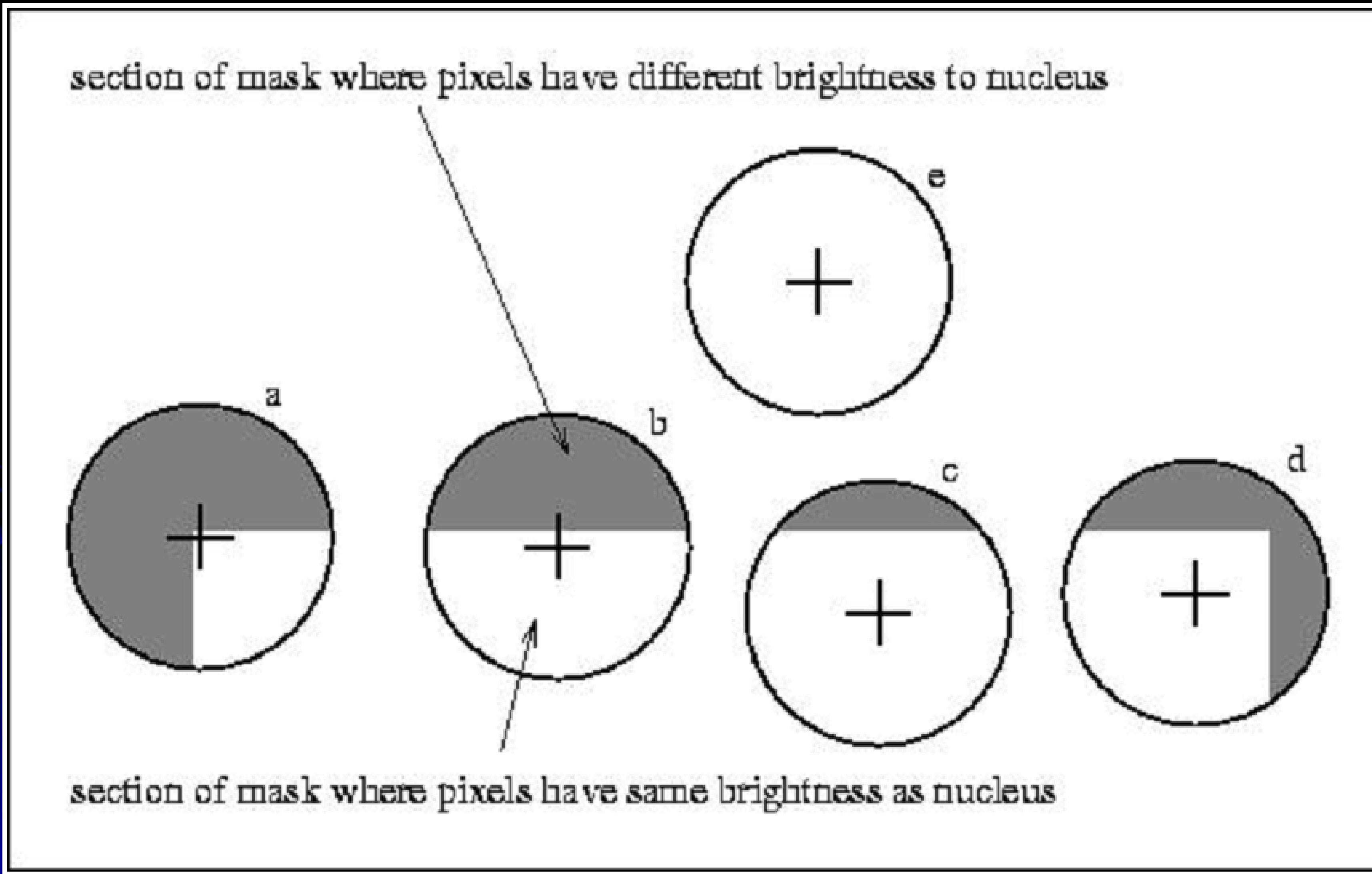


SUSAN



- Intenzita každého bodu v okne sa porovná s intenzitou centra (nucleus)
- Vyznačíme oblasť okna, v ktorej majú body rovnakú (podobnú) intenzitu = Univalue Segment Assimilating Nucleus (USAN)
- USAN pre každý bod obrazu
- Hodnota USAN je malá po stranách hrany a ešte menšia pri rohoch
- Najmenšia hodnota USAN = Smallest USAN = SUSAN
- The local minima of the USAN map represents corners in the image.


nucleus of mask
boundary of mask
e
a
b
c
d
dark area
light area


section of mask where pixels have different brightness to nucleus
e
a
b
c
d
section of mask where pixels have same brightness as nucleus