



Histogram priestorového rozloženia farieb

Farba, umiestnenie, štandardná odchýlka

$$S_I(i) = (h_I(i), \mathbf{b}_I(i), \sigma_I(i)), \quad i = 1, \dots, C_p$$

priemerné umiestnenie

$$\mathbf{b}_i = (\bar{x}_i, \bar{y}_i)$$

$$\bar{x}_i = \frac{1}{N \cdot A_i} \sum_{c(\mathbf{p})=C_i} x,$$

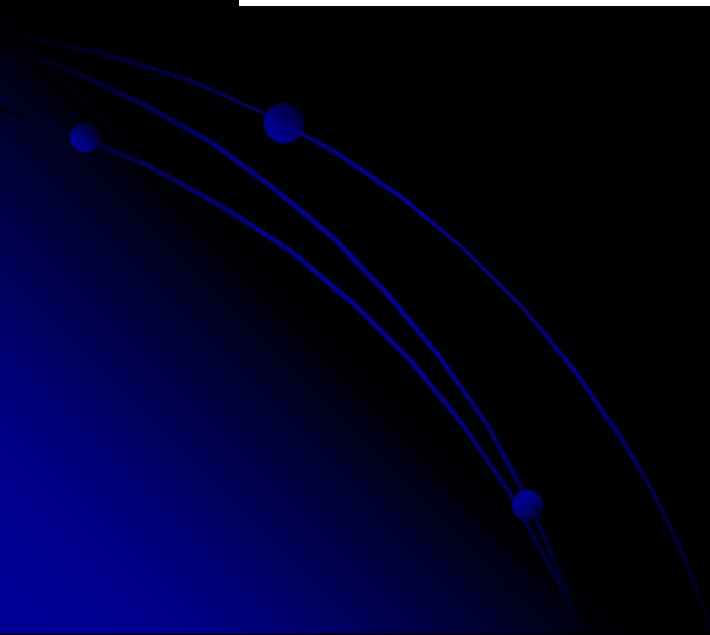
$$\bar{y}_i = \frac{1}{M \cdot A_i} \sum_{c(\mathbf{p})=C_i} y,$$

$$\sigma_i = \sqrt{\frac{1}{A_i} \sum_{c(\mathbf{p})=C_i} d(\mathbf{p}, \mathbf{b}_i)},$$

Farebný korelogram

Do matice sa zapisujú počty výskytov dvojíc (c_i, c_j) farieb bodov v určenej vzdialenosti k

$$M_k(i, j) = |\{(\mathbf{p}) \mid f(\mathbf{p}) = c_i \ \& \ f(\mathbf{q}) = c_j \ \& \ d(\mathbf{p}, \mathbf{q}) = k\}|$$



Vektor farebnej koherencie

stupeň príslušnosti farebných bodov k spojitaj oblasti

A	A	A	A	B	C	C	C
A	D	E	E	E	C	C	C
A	E	D	E	F	F	F	F
E	E	G	G	F	H	I	I
G	G	G	G	F	H	H	H
G	G	J	J	H	H	K	K
G	L	J	J	H	H	J	J
G	J	J	M	J	J	J	N

Región	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Farba														
Veľkosť	6	1	6	2	7	6	10	8	2	11	2	1	1	1

Farba				
α	15	23	6	10
β	0	0	6	4

MPEG7 dominantná farba

$$F = \{ \{c_i, p_i, v_i\}, s \}$$

Reprezentatívne farby

Percentuálne zastúpenie

Variancia

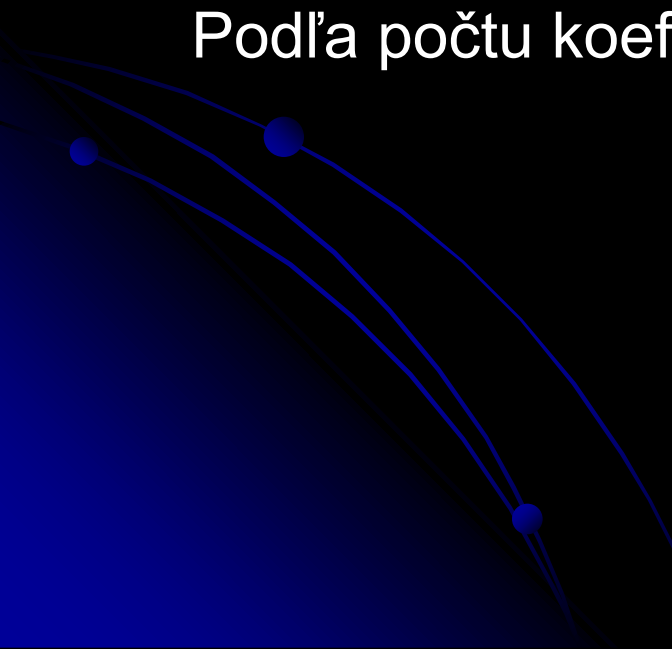
- Priestorová koherencia

Ako „veľmi“ sú spojené body majúce dominantnú farbu

MPEG7 škálovateľná farba

Počet tried	16	32	64	128	256
Odtieň	4	8	8	8	16
Saturácia	2	2	2	4	4
Hodnota	2	2	4	4	4

Hodnoty zakódované pomocou Haarovej transformácie
Podľa počtu koeficientov HT škálujeme histogram



MPEG7 rozloženie farieb



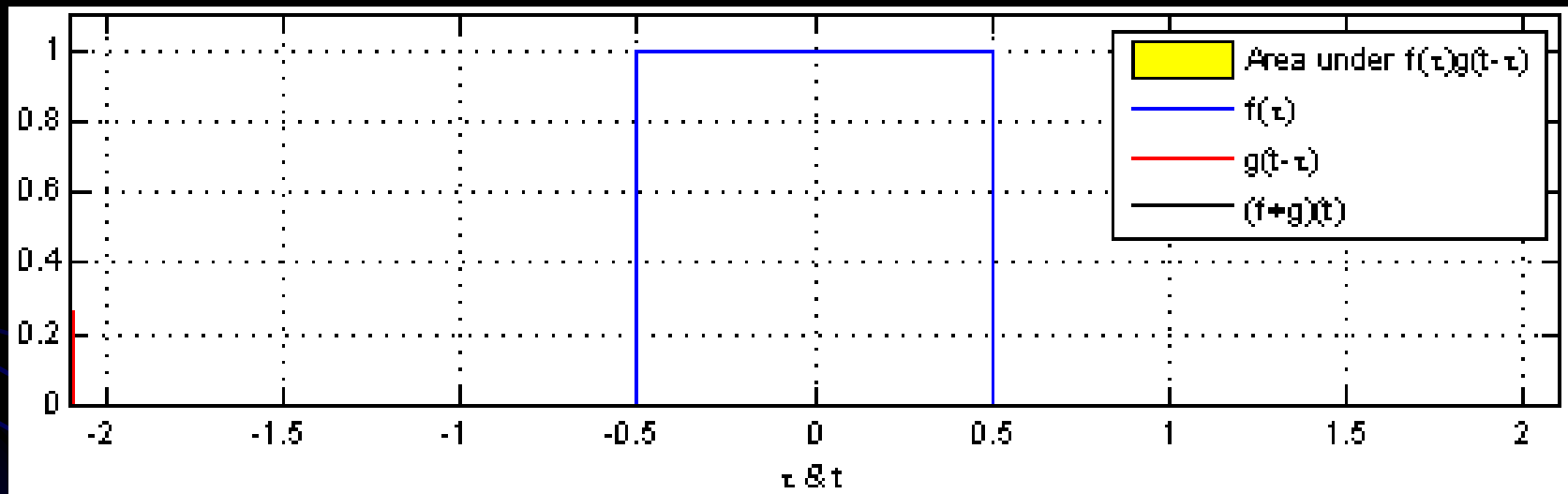
1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	17
18	19	20	21	22	23	16	25
26	27	28	29	30	31	24	33
34	35	36	37	38	39	32	41
42	43	44	45	46	47	40	49
50	51	52	53	54	55	48	58
59	60	61	62	63	56	57	64

Textúra

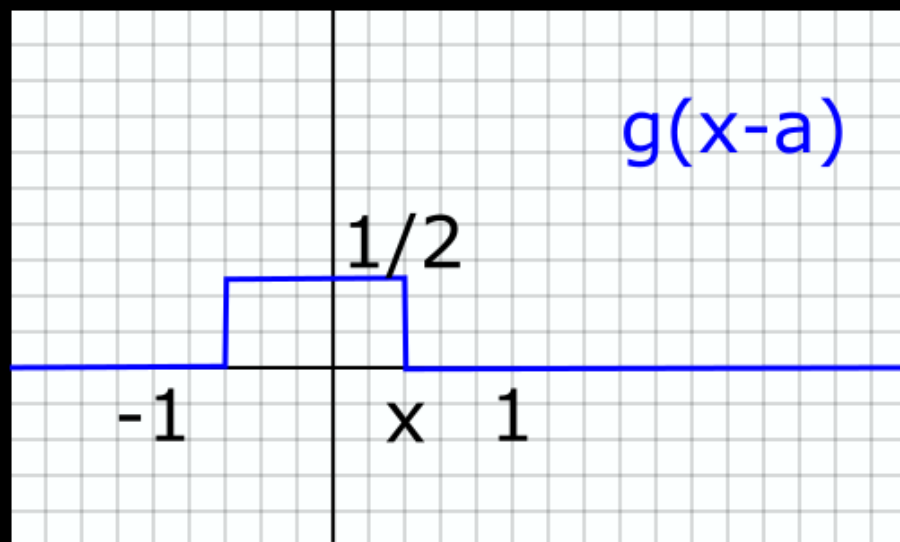
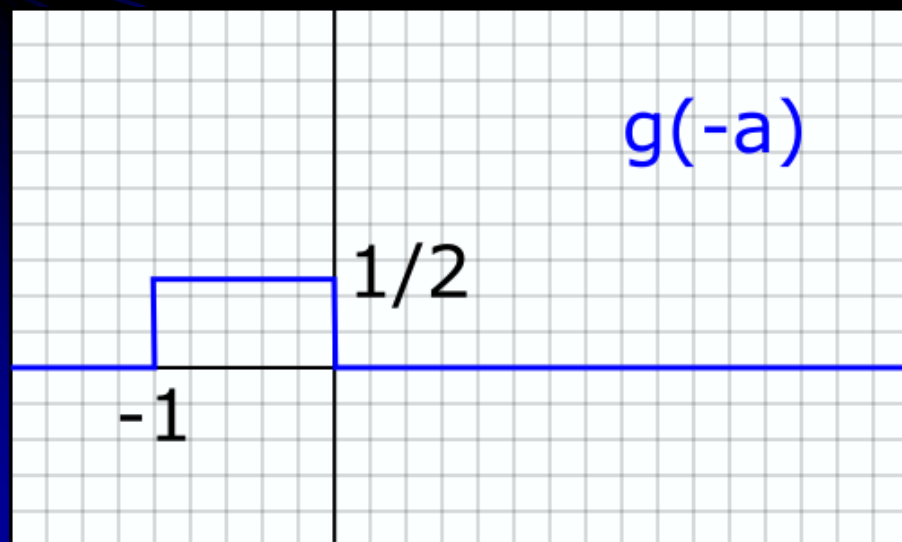
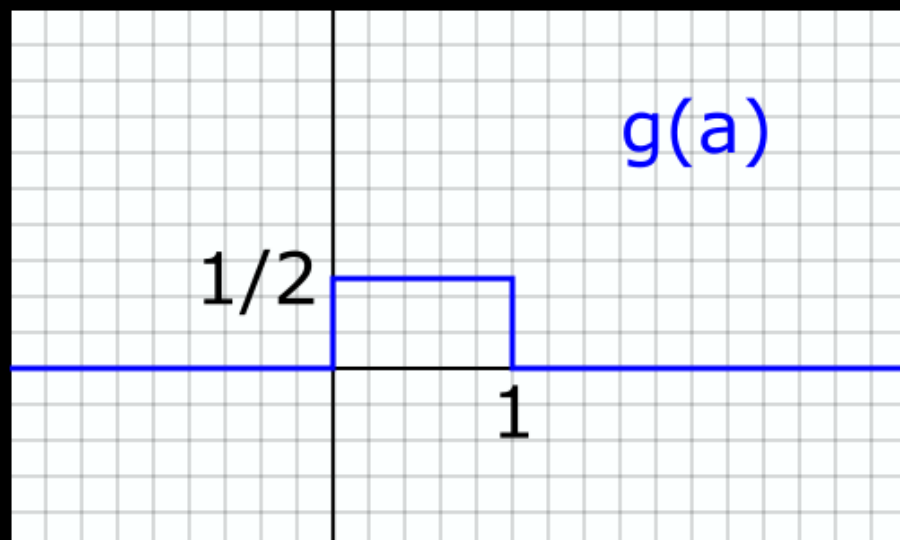
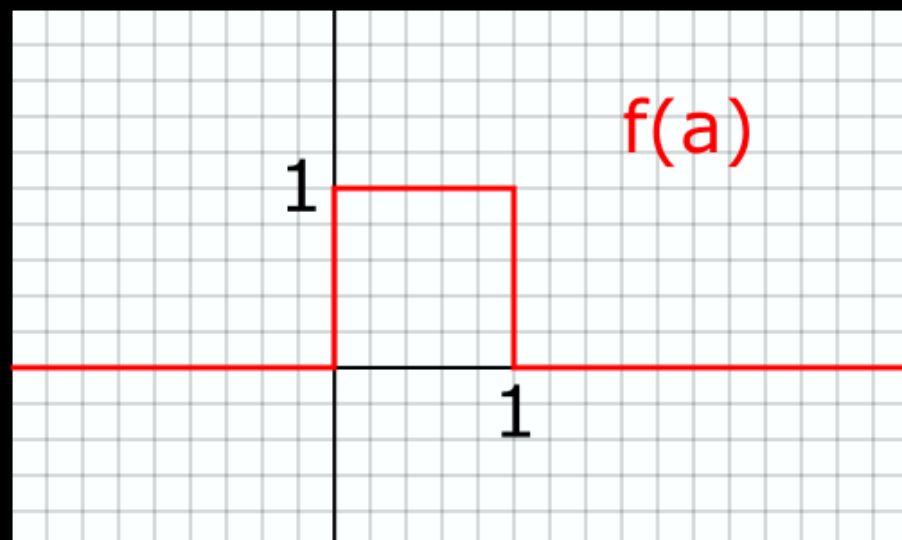


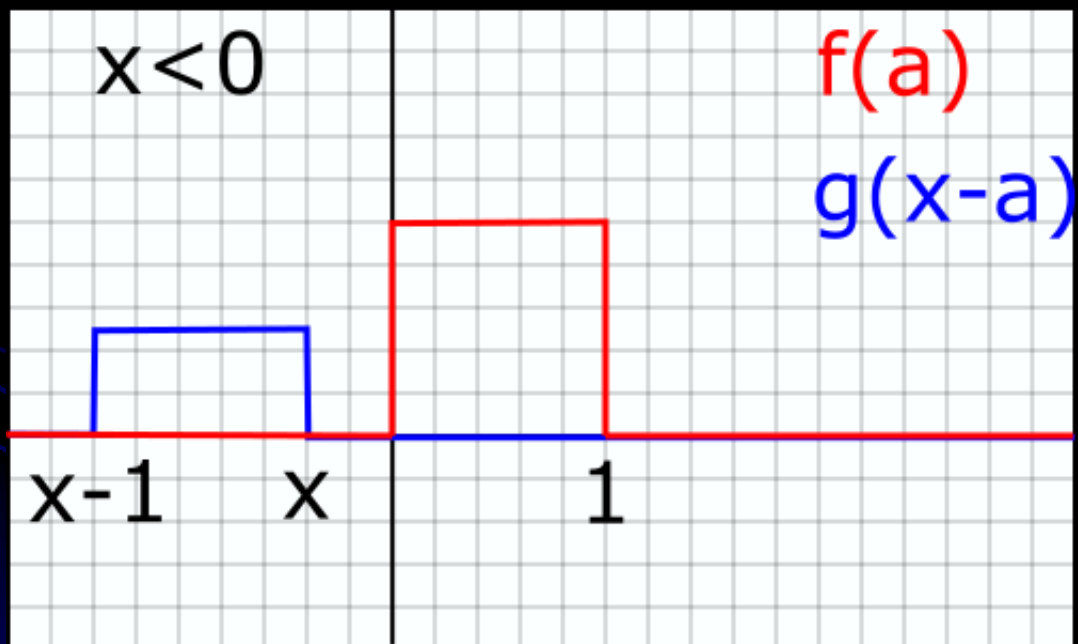
konvolúcia

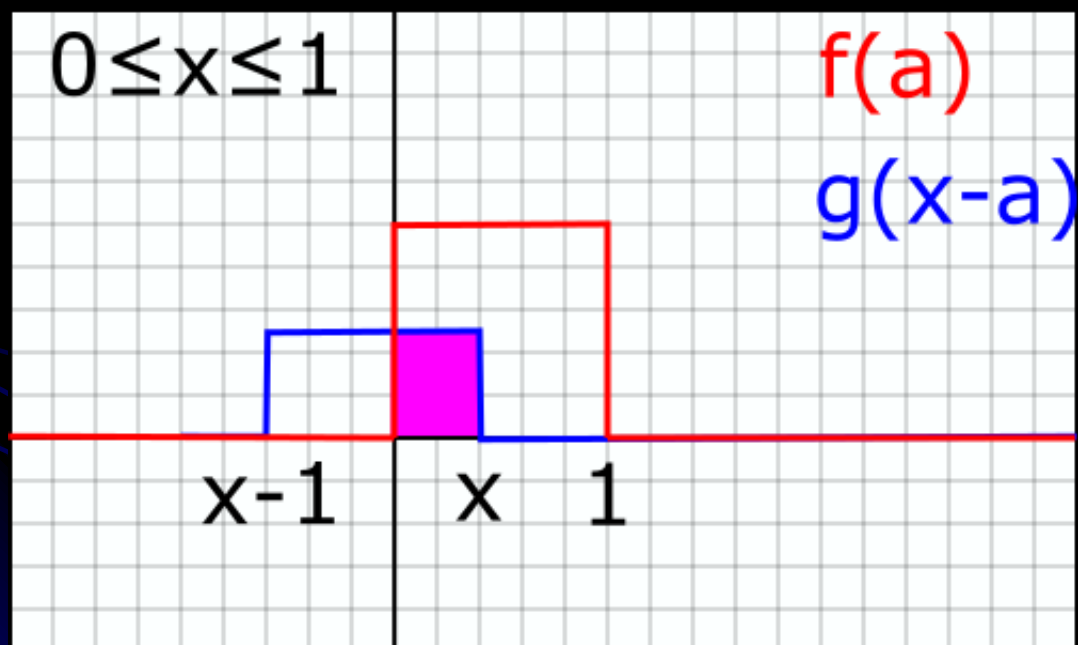
$$\int_{-\infty}^{\infty} f(a)g(x-a)da$$



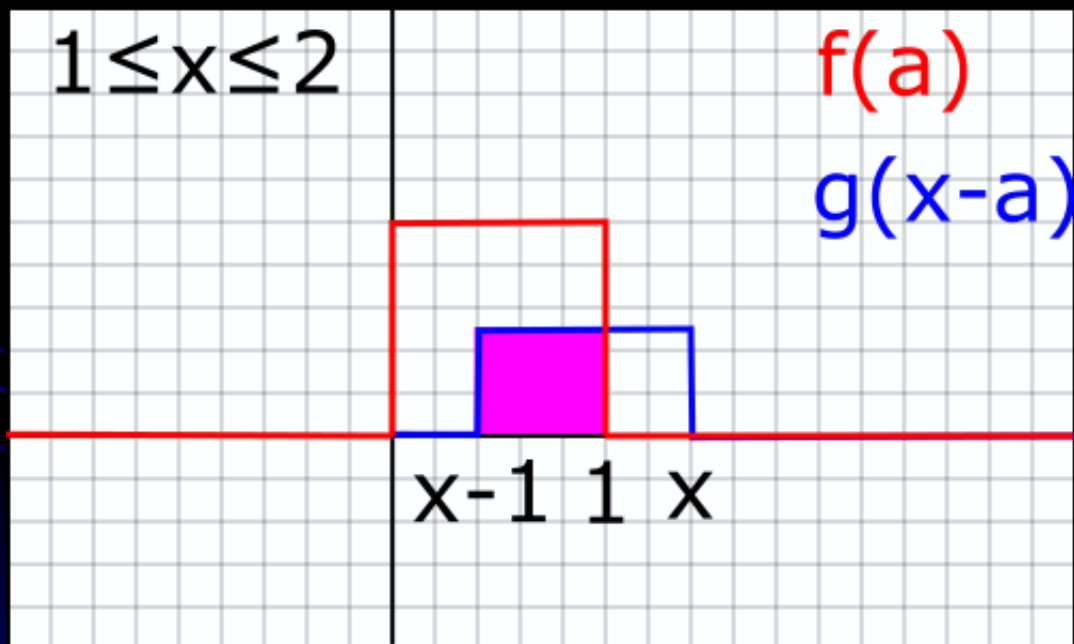
$$\int_{-\infty}^{\infty} f(a)g(x-a)da$$







$$\int_0^x 1 \cdot \frac{1}{2} da = \frac{x}{2}$$



$$\int_{x-1}^1 1 \frac{1}{2} da = 1 - \frac{x}{2}$$

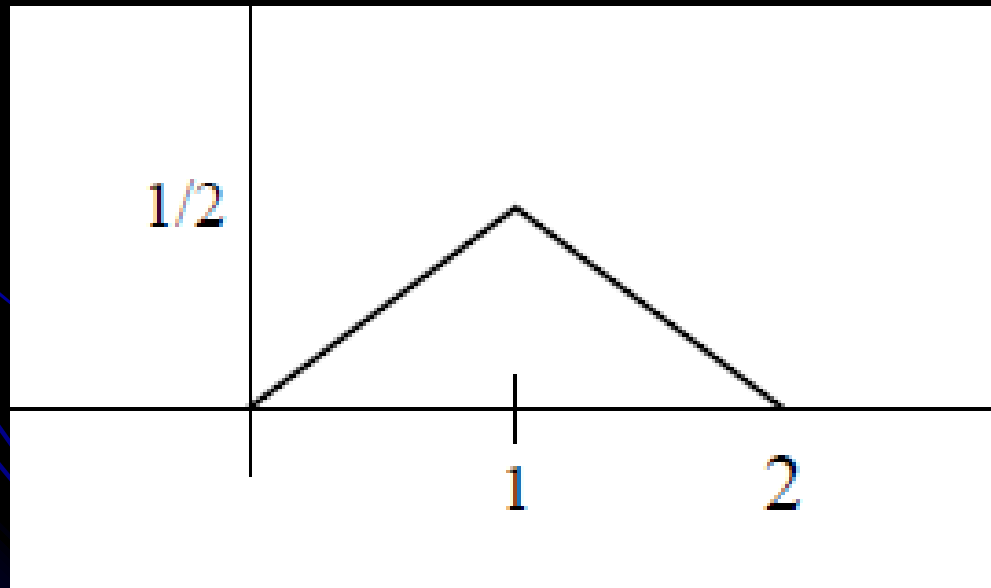
$$x > 2$$

$f(a)$

$g(x-a)$

1 $x-1$ x

$$(f * g)(x) = \begin{cases} x/2 & 0 \leq x \leq 1 \\ 1 - x/2 & 1 \leq x \leq 2 \\ 0 & \text{elsewhere} \end{cases}$$



Konvolúcia 2D

Diskrétny 1D signál

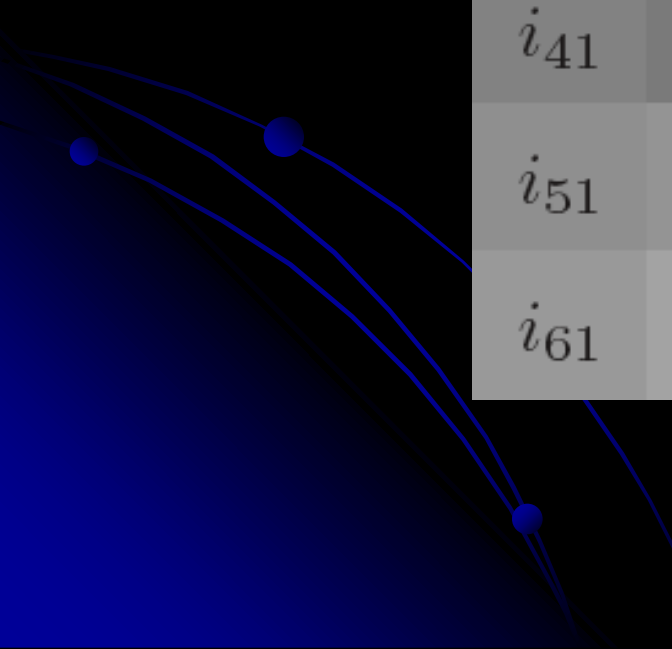
$$f(k) = (I * w)(k) = \sum_{n=-\infty}^{\infty} I(n)w(k-n)$$

$$f(k) = (I * w)(k) = \sum_{n=-a}^a I(n)w(k-n)$$

Diskrétny 2D signál

$$f(k, l) = (I * w)(k, l) = \sum_{n=-\infty}^{\infty} \sum_{m=-\infty}^{\infty} I(n, m)w(k-n, l-m)$$

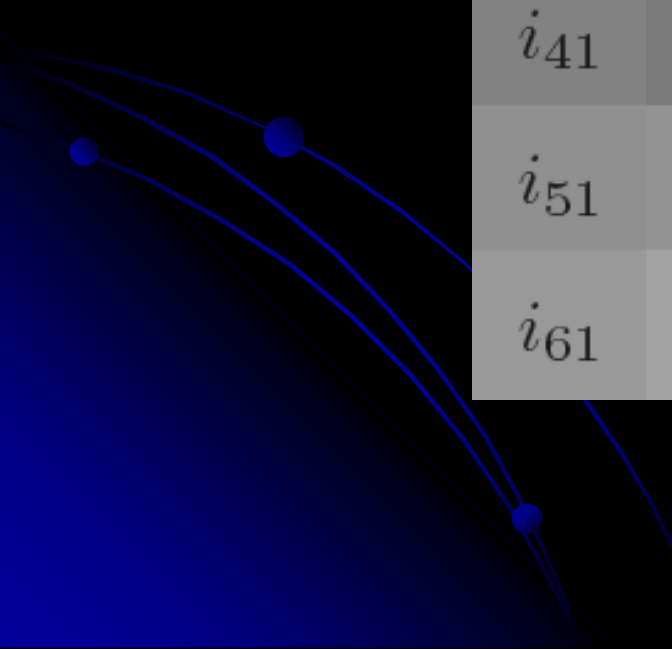
$$f(k, l) = (I * w)(k, l) = \sum_{n=-a}^a \sum_{m=-b}^b I(n, m)w(k-n, l-m)$$



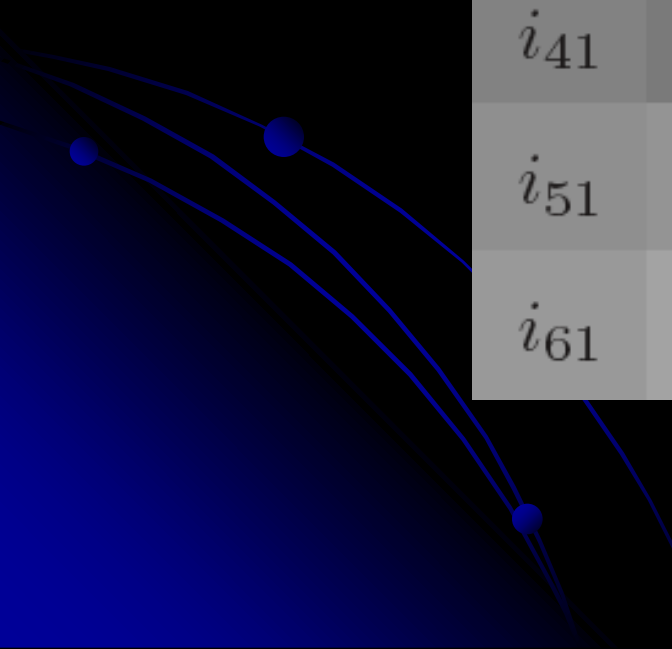
i_{11}	i_{12}	i_{13}	i_{14}	i_{15}	i_{16}
i_{21}	i_{22}	i_{23}	i_{24}	i_{25}	i_{26}
i_{31}	i_{32}	i_{33}	i_{34}	i_{35}	i_{36}
i_{41}	i_{42}	i_{43}	i_{44}	i_{45}	i_{46}
i_{51}	i_{52}	i_{53}	i_{54}	i_{55}	i_{56}
i_{61}	i_{62}	i_{63}	i_{64}	i_{65}	i_{66}

w_1	w_2	w_3	i_{14}	i_{15}	i_{16}
w_4	w_5	w_6	i_{24}	i_{25}	i_{26}
w_7	w_8	w_9	i_{34}	i_{35}	i_{36}
i_{41}	i_{42}	i_{43}	i_{44}	i_{45}	i_{46}
i_{51}	i_{52}	i_{53}	i_{54}	i_{55}	i_{56}
i_{61}	i_{62}	i_{63}	i_{64}	i_{65}	i_{66}

i_{11}	w_1	w_2	w_3	i_{15}	i_{16}
i_{21}	w_4	w_5	w_6	i_{25}	i_{26}
i_{31}	w_7	w_8	w_9	i_{35}	i_{36}
i_{41}	i_{42}	i_{43}	i_{44}	i_{45}	i_{46}
i_{51}	i_{52}	i_{53}	i_{54}	i_{55}	i_{56}
i_{61}	i_{62}	i_{63}	i_{64}	i_{65}	i_{66}



i_{11}	i_{12}	w_1	w_2	w_3	i_{16}
i_{21}	i_{22}	w_4	w_5	w_6	i_{26}
i_{31}	i_{32}	w_7	w_8	w_9	i_{36}
i_{41}	i_{42}	i_{43}	i_{44}	i_{45}	i_{46}
i_{51}	i_{52}	i_{53}	i_{54}	i_{55}	i_{56}
i_{61}	i_{62}	i_{63}	i_{64}	i_{65}	i_{66}



i_{11}	i_{12}	i_{13}	w_1	w_2	w_3
i_{21}	i_{22}	i_{23}	w_4	w_5	w_6
i_{31}	i_{32}	i_{33}	w_7	w_8	w_9
i_{41}	i_{42}	i_{43}	i_{44}	i_{45}	i_{46}
i_{51}	i_{52}	i_{53}	i_{54}	i_{55}	i_{56}
i_{61}	i_{62}	i_{63}	i_{64}	i_{65}	i_{66}

i_{11}	i_{12}	i_{13}	i_{14}	i_{15}	i_{16}
w_1	w_2	w_3	i_{24}	i_{25}	i_{26}
w_4	w_5	w_6	i_{34}	i_{35}	i_{36}
w_7	w_8	w_9	i_{44}	i_{45}	i_{46}
i_{51}	i_{52}	i_{53}	i_{54}	i_{55}	i_{56}
i_{61}	i_{62}	i_{63}	i_{64}	i_{65}	i_{66}

$$f(k, l) = (I * w)(k, l) = \sum_{n=-a}^a \sum_{m=-b}^b I(n, m) w(k - n, l - m)$$

$f(0,0) = ?$

w_1	w_2	w_3				
w_4	w_5	w_6	i_{13}	i_{14}	i_{15}	i_{16}
w_7	w_8	w_9	i_{23}	i_{24}	i_{25}	i_{26}
			i_{31}	i_{32}	i_{33}	i_{34}
			i_{41}	i_{42}	i_{43}	i_{44}
			i_{51}	i_{52}	i_{53}	i_{54}
			i_{61}	i_{62}	i_{63}	i_{64}

Pridáme okraje

w_1	w_2	w_3	i_{63}	i_{64}	i_{65}	i_{66}	i_{61}
w_4	w_5	w_6	i_{13}	i_{14}	i_{15}	i_{16}	i_{11}
w_7	w_8	w_9	i_{23}	i_{24}	i_{25}	i_{26}	i_{21}
i_{36}	i_{31}	i_{32}	i_{33}	i_{34}	i_{35}	i_{36}	i_{31}
i_{46}	i_{41}	i_{42}	i_{43}	i_{44}	i_{45}	i_{46}	i_{41}
i_{56}	i_{51}	i_{52}	i_{53}	i_{54}	i_{55}	i_{56}	i_{51}
i_{66}	i_{61}	i_{62}	i_{63}	i_{64}	i_{65}	i_{66}	i_{61}
i_{16}	i_{11}	i_{12}	i_{13}	i_{14}	i_{15}	i_{16}	i_{11}

w_1	w_2	w_3	0	0	0	0	0
w_4	w_5	w_6	i_{13}	i_{14}	i_{15}	i_{16}	0
w_7	w_8	w_9	i_{23}	i_{24}	i_{25}	i_{26}	0
0	i_{31}	i_{32}	i_{33}	i_{34}	i_{35}	i_{36}	0
0	i_{41}	i_{42}	i_{43}	i_{44}	i_{45}	i_{46}	0
0	i_{51}	i_{52}	i_{53}	i_{54}	i_{55}	i_{56}	0
0	i_{61}	i_{62}	i_{63}	i_{64}	i_{65}	i_{66}	0
0	0	0	0	0	0	0	0

Korelácia

$$f(k, l) = (I * w)(k, l) = \sum_{n=-a}^a \sum_{m=-b}^b I(n, m) w(k + n, l + m)$$

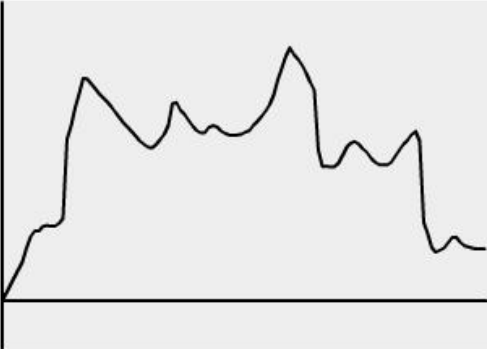
$$f(k, l) = (I * w)(k, l) = \sum_{n=-a}^a \sum_{m=-b}^b I(n, m) w(k - n, l - m)$$

Pri korelácii nezrkadlíme jadro

<http://graphics.stanford.edu/courses/cs178/applets/convolution.html>

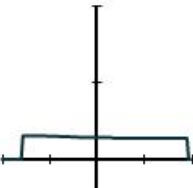
Convolution

1D signal
(draw to change)



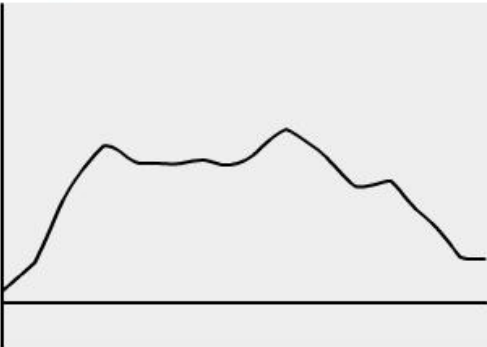
1D filter

- ☐ rect
- ☐ big rect
- ☐ gaussian
- ☐ sharpen
- ☐ shift
- ☒ custom



☒ animate
normalize

1D result



2D signal
select image:
hummi... v



2D filter

- ☐ rect
- ☐ big rect
- ☐ gaussian
- ☐ sharpen
- ☐ edges
- ☐ shift
- ☐ hand shake
- ☒ custom

0.00	0.00	0.00	0.00	0.00
0.00	0.11	0.11	0.11	0.00
0.00	0.11	0.11	0.11	0.00
0.00	0.11	0.11	0.11	0.00
0.00	0.00	0.00	0.00	0.00

normalize

2D result



Help
Reset

Korelácia

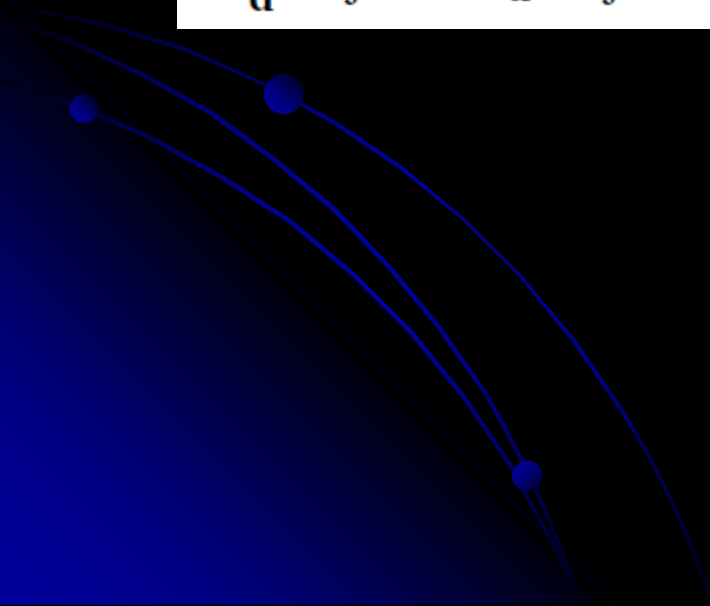
$$f(k, l) = (I * w)(k, l) = \sum_{n=-a}^a \sum_{m=-b}^b I(n, m) w(k + n, l + m)$$

Autokorelácia

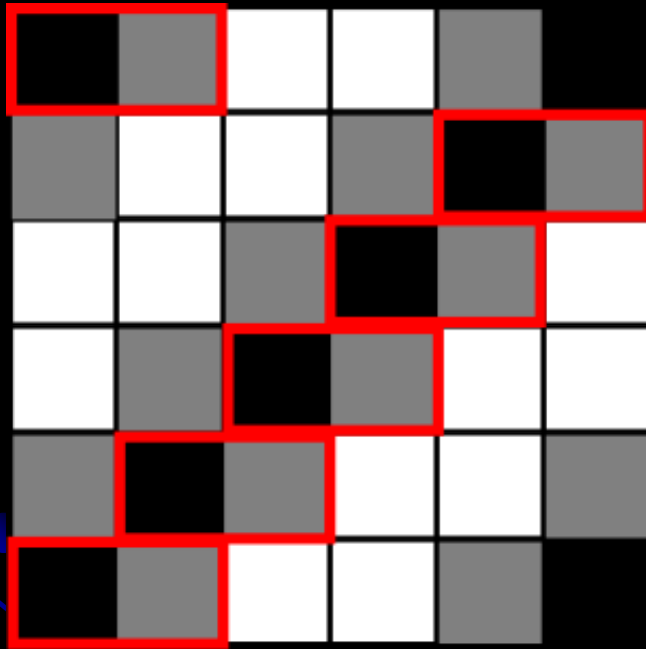
$$\rho(u, v) = \frac{MN}{(M - u)(N - v)} \frac{\sum_{x=1}^{M-u} \sum_{y=1}^{N-v} I(x, y) I(x + u, y + v)}{\sum_{x=1}^M \sum_{y=1}^N I^2(x, y)}$$

Matica opakovaných výskytov

$$M_{\mathbf{d}}(i, j) = |\{(x, y) \mid f(x, y) = i \ \& \ f(x + d_x, y + d_y) = j\}|$$

$$M_{\mathbf{d}}^s(i, j) = M_{\mathbf{d}}(i, j) + M_{-\mathbf{d}}(i, j)$$


$(1,0)$



	6	6	0
	6	0	6
	0	6	0

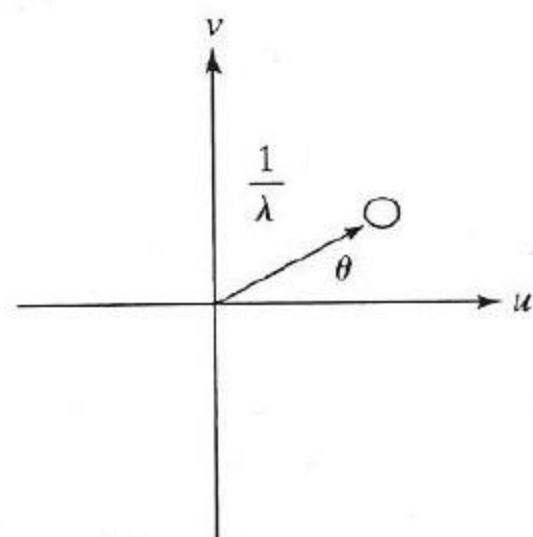
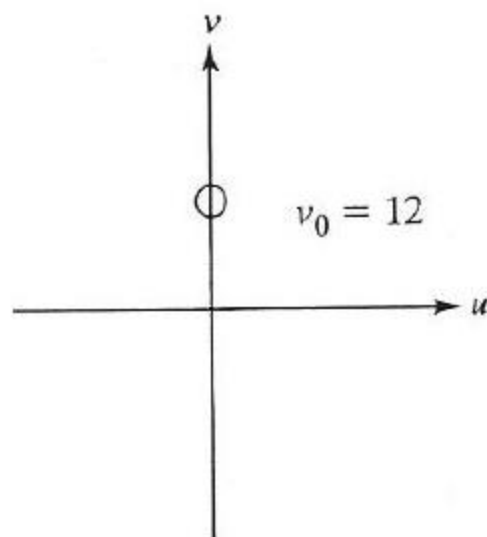
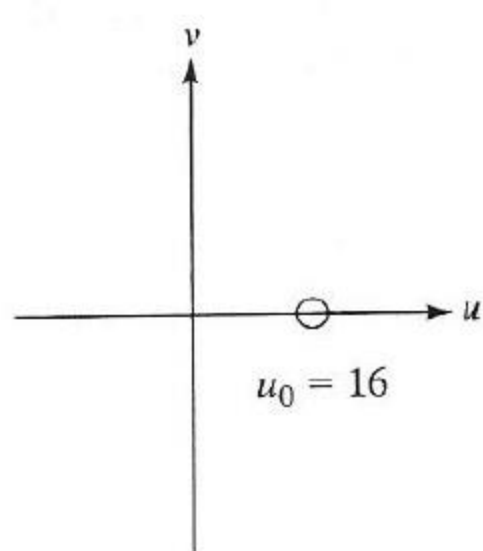
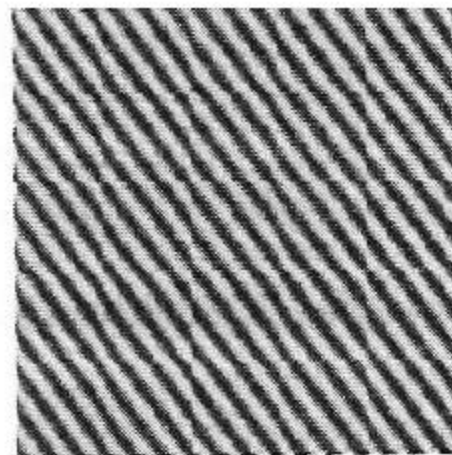
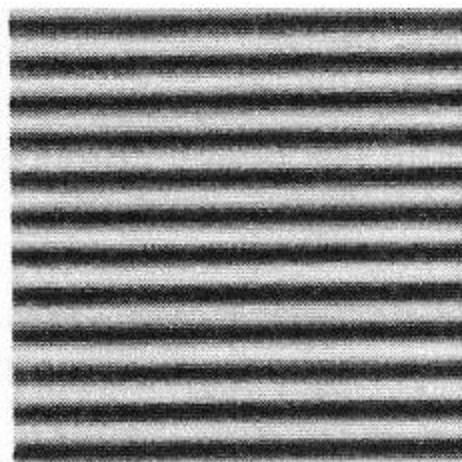
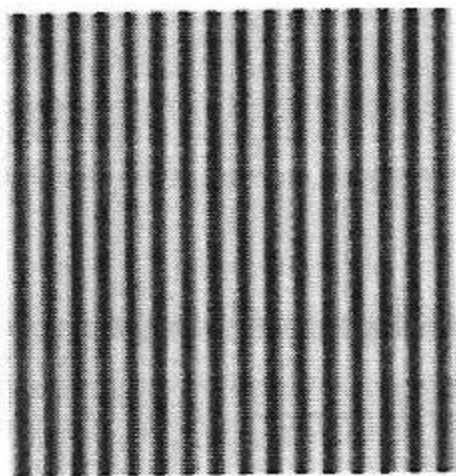
entropia, energia, momenty, inverzné momenty,
maximálna hodnota, korelácia, kontrast,
homogénnosť

Kontrast	$C = \frac{1}{(L-1)^2} \sum_{k=0}^{L-1} k^2 \sum_{i,j; i-j =k} M_d(i, j)$
Energia	$H = \sum_{i=1}^L \sum_{j=1}^L M_d^2(i, j)$
Homogénnosť	$S = \sum_{i=1}^L \sum_{j=1}^L \frac{M_d(i, j)}{1+ i-j }$

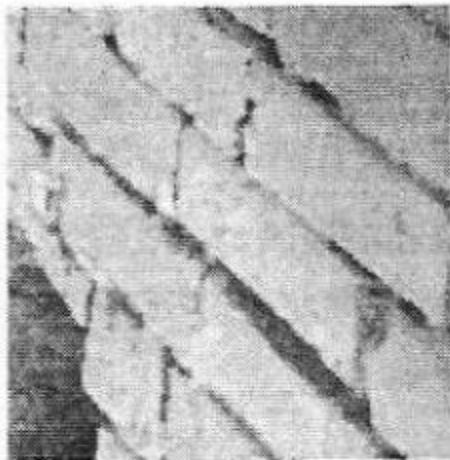
Diskrétna Fourierova transformácia

$$F(u, v) = R(u, v) + iI(u, v)$$

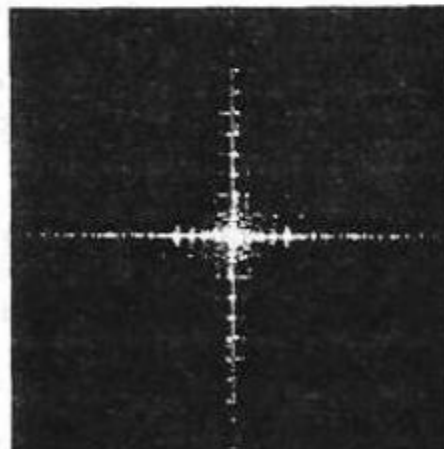
Amplitúdové spektrum	$ F(u, v) = \sqrt{R^2(u, v) + I^2(u, v)}$
Fázové spektrum	$\phi(u, v) = \arctan \frac{I(u, v)}{R(u, v)}$
Výkonové spektrum	$P(u, v) = F(u, v) ^2 = R^2(u, v) + I^2(u, v)$



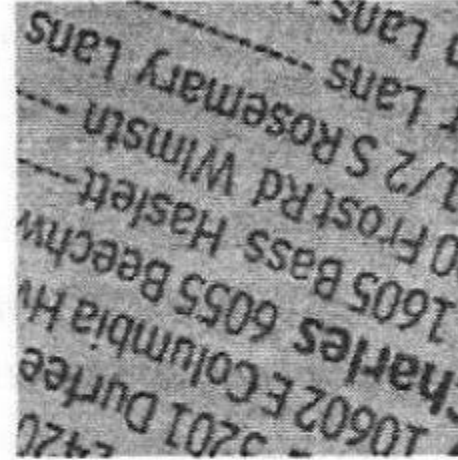
Regulárnost'



Jemnost'

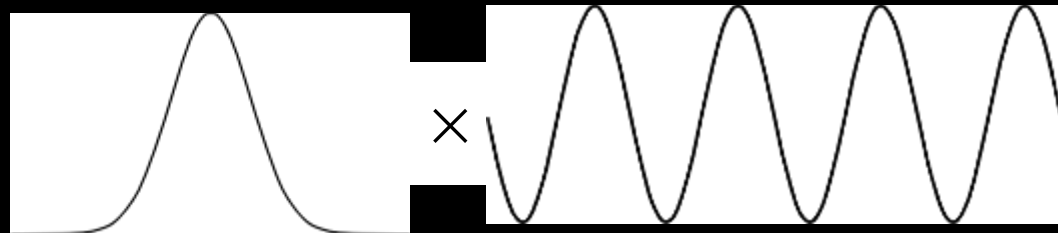


Smerovost'



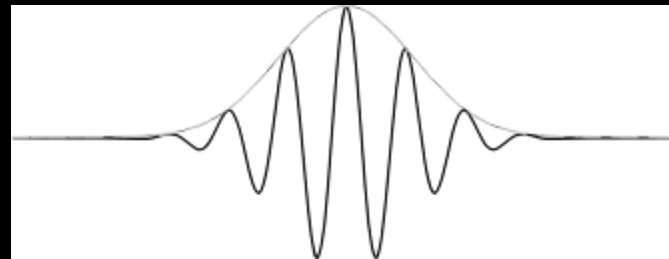
Gaborove filtre

$$h(x, y, \lambda, \theta, \psi, \sigma_x, \sigma_y) = g(x', y', \theta, \sigma_x, \sigma_y) e(x', \theta, \lambda, \psi)$$



Gauss

Sínusoida



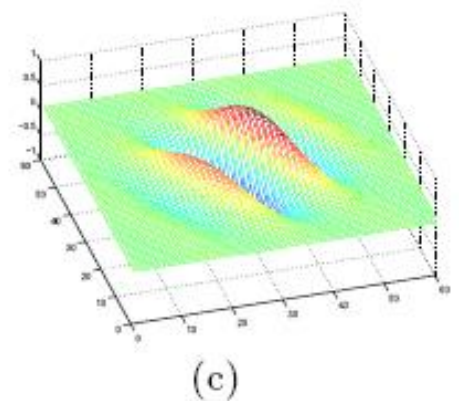
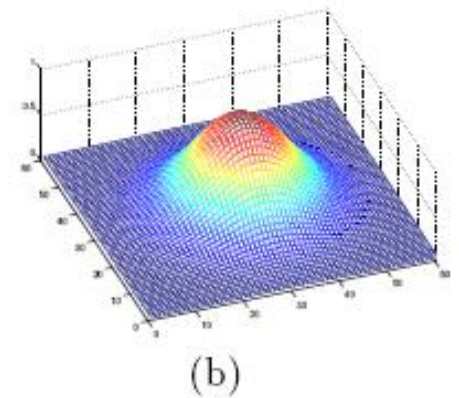
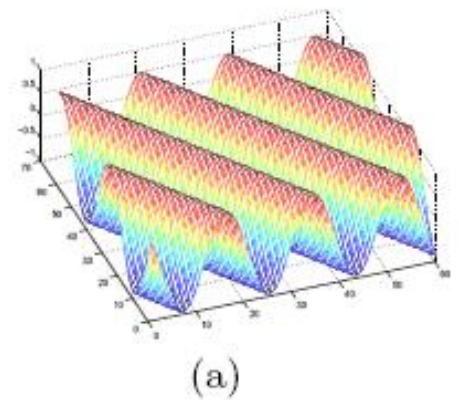
Gabor

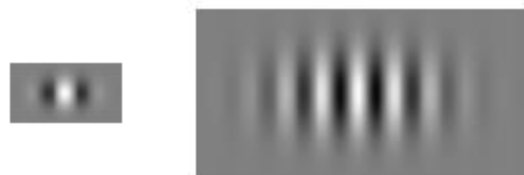
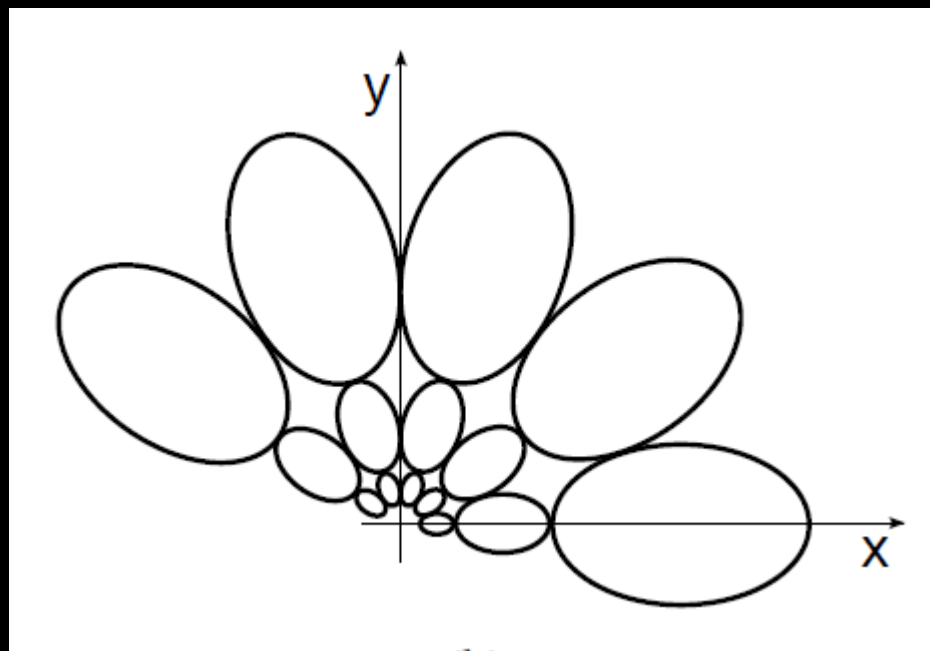
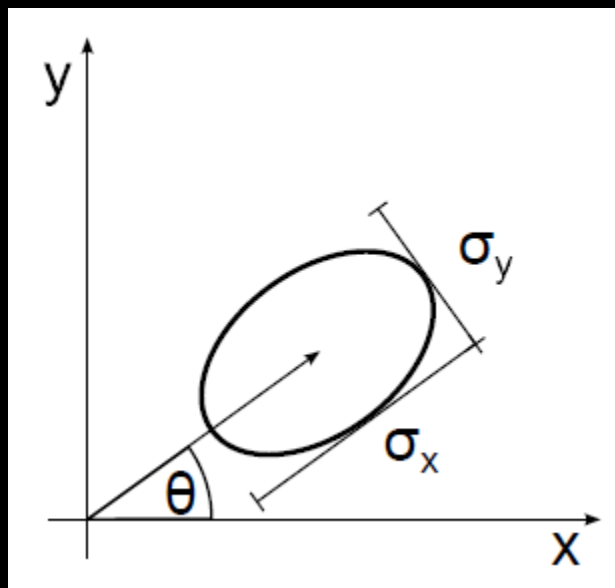
$$h(x, y, \lambda, \theta, \psi, \sigma_x, \sigma_y) = g(x', y', \theta, \sigma_x, \sigma_y) e(x', \theta, \lambda, \psi)$$

$$\begin{aligned} e(x', \theta, \lambda, \psi) &= \exp(2\pi i f x' + \psi) = \\ &= \exp\left[i\left(2\pi \frac{x'}{\lambda} + \psi\right)\right] = \\ &= \cos\left(2\pi \frac{x'}{\lambda} + \psi\right) + i \sin\left(2\pi \frac{x'}{\lambda} + \psi\right) \end{aligned}$$

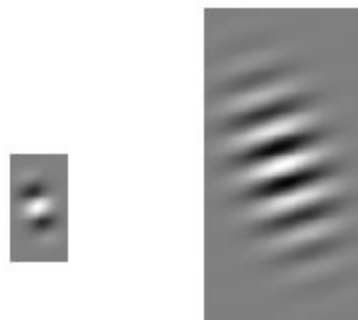
$$g(x', y', \theta, \sigma_x, \sigma_y) = \frac{1}{2\pi\sigma_x\sigma_y} \exp\left[-\left(\frac{x'^2}{2\sigma_x^2} + \frac{y'^2}{2\sigma_y^2}\right)\right]$$

$$(x', y') = (x \cos \theta + y \sin \theta, -x \sin \theta + y \cos \theta)$$

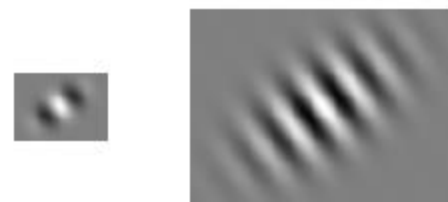




(a) $\theta = 0$.



(b) $\theta = 2\pi/5$.



(c) $\theta = 4\pi/5$.



(a) Vstupný obraz.



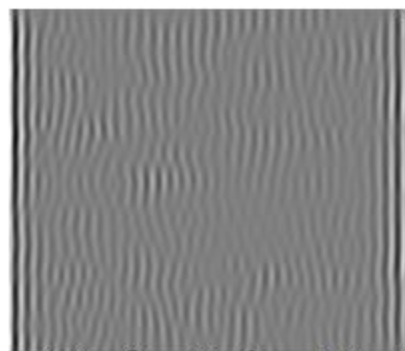
(b) $\theta = 0, \lambda = 10.$



(c) $\theta = 2\pi/5, \lambda = 10.$



(d) $\theta = 4\pi/5, \lambda = 10.$



(e) $\theta = 0, \lambda = 30.$



(f) $\theta = 2\pi/5, \lambda = 30.$



(g) $\theta = 4\pi/5, \lambda = 30.$

$$h_{Re}(x, y, \Omega) = \frac{1}{2\pi\sigma_x\sigma_y} \exp \left[- \left(\frac{x'^2}{2\sigma_x^2} + \frac{y'^2}{2\sigma_y^2} \right) \right] \cos \left(2\pi \frac{x'}{\lambda} + \psi \right)$$

$$h_{Im}(x, y, \Omega) = \frac{1}{2\pi\sigma_x\sigma_y} \exp \left[- \left(\frac{x'^2}{2\sigma_x^2} + \frac{y'^2}{2\sigma_y^2} \right) \right] \sin \left(2\pi \frac{x'}{\lambda} + \psi \right)$$

$$J_{Re}(x, y, \Omega) = I(x, y) * h_{Re}(x, y, \Omega)$$

$$J_{Im}(x, y, \Omega) = I(x, y) * h_{Im}(x, y, \Omega)$$

$$E(x, y, \Omega) = J_{Re}^2(x, y, \Omega) + J_{Im}^2(x, y, \Omega),$$

$$M(x, y, \Omega) = \sqrt{\bar{E}}(x, y, \Omega).$$

$$\bar{E}(\Omega) = \frac{1}{N} \sum_x \sum_y E(x, y, \Omega)$$

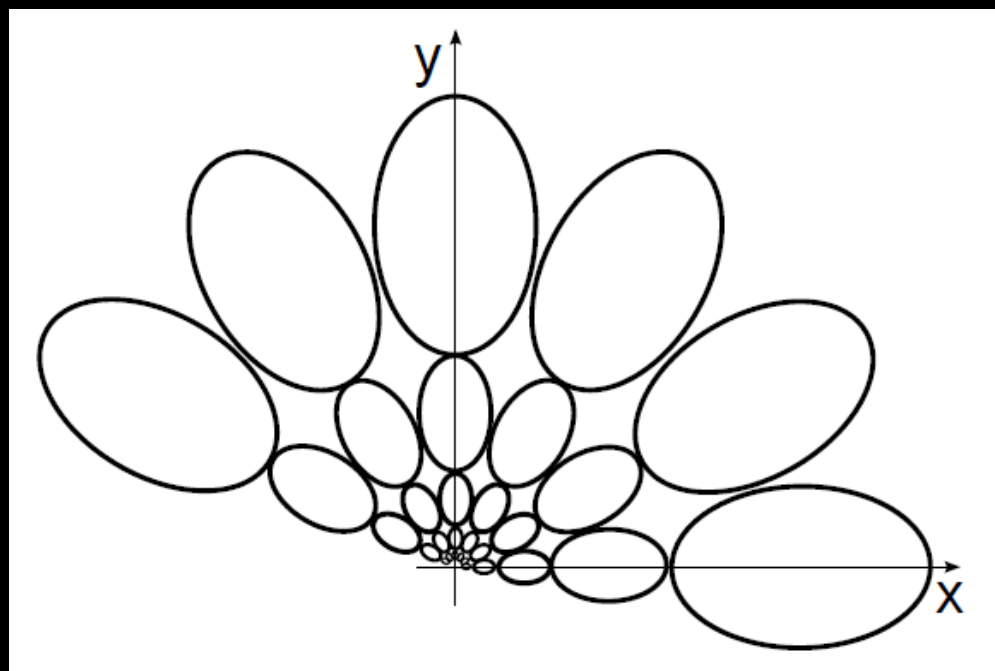
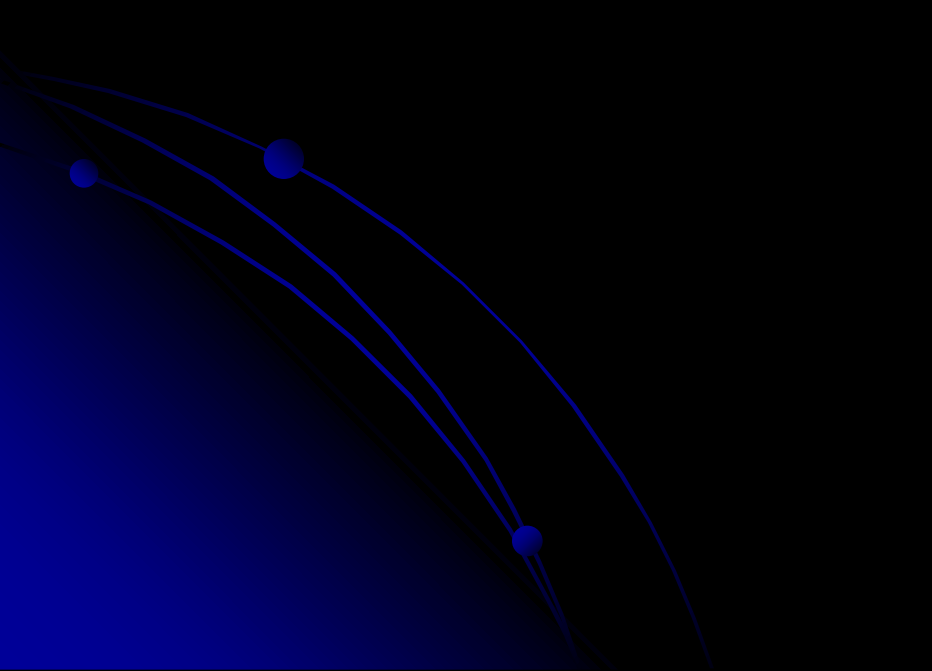
MPEG7 homogénne textúry

Množina 30 filtrov orientácia (6x5) škála (napr. Gabor)

Priemer a štandardná odchýlka odoziev (60 údajov)

Priemer a štandardná odchýlka intenzity (2 údaje)

$$\{E_1, \text{Std}(E_1), \dots, E_{30}, \text{Std}(E_{30}), \bar{I}, \text{Std}(I)\}$$



MPEG7 prehl'adávanie textúr

12 bitový deskriptor

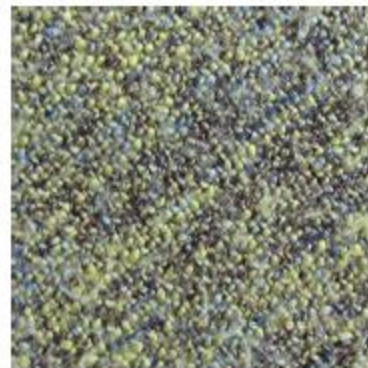
2 bity: regularita

2x3 bity: smery, ktoré najviac vystihujú orientáciu textúry

2x2 bity: škály, ktoré najviac vystihujú hrubosť (zrornosť)

6 smerov: 0° po 150° v 30° krokoch

4 úrovne zrornosti: 0= jemná textúra, 3= veľmi zrorná textúra



Obrázok 8.6: Textúry s rôznou mierou pravidelnosti zoradené od najmenej po najviac pravidelnú.

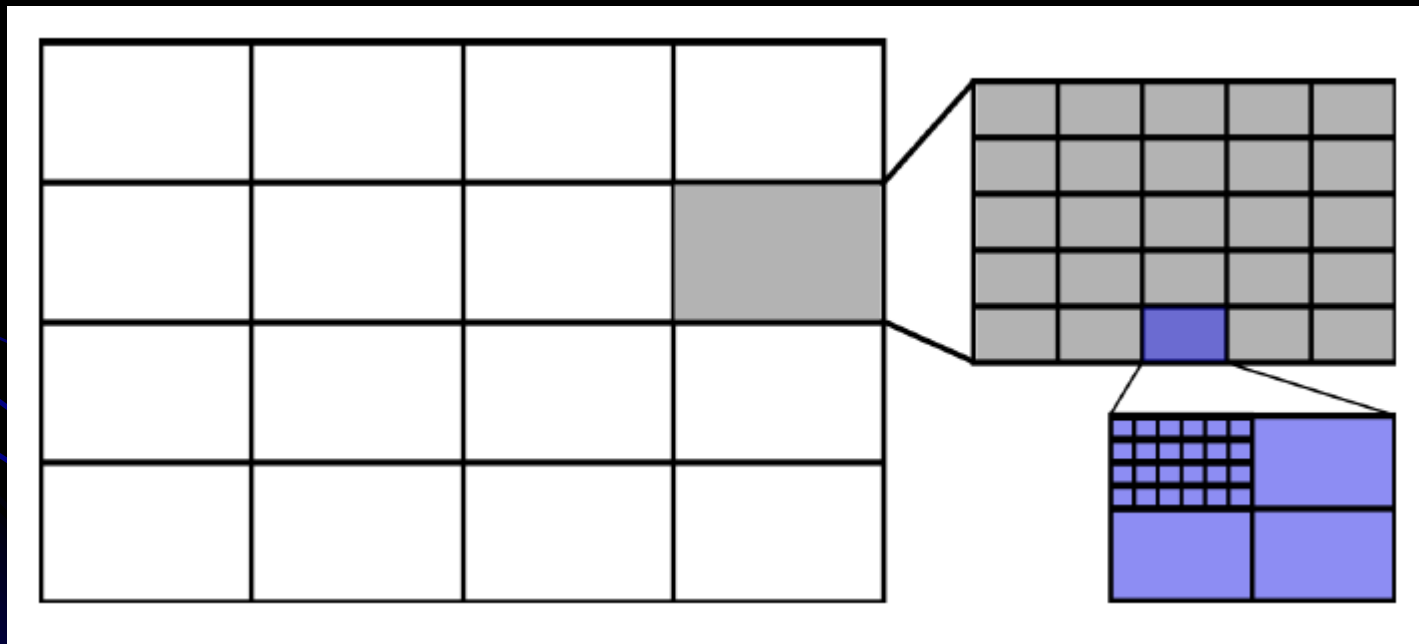


Obrázok 8.7: Textúry s rôznou mierou zrnitosti.

MPEG7 histogram lokálnych hrán

4x4 rozdelenie obrazu

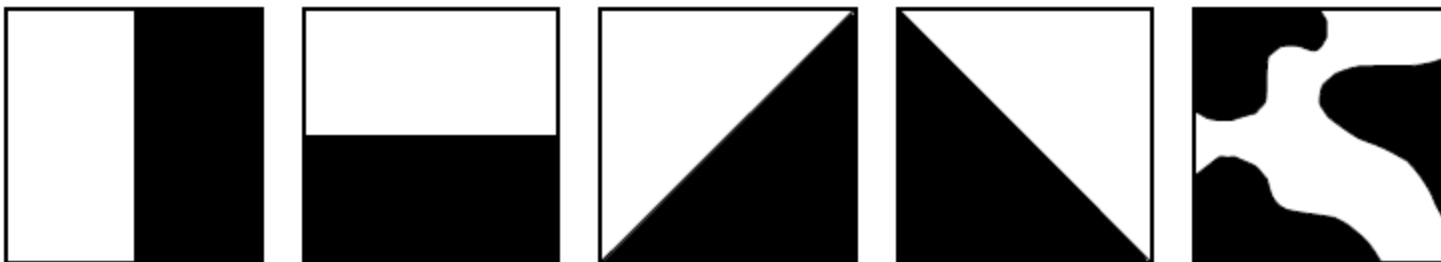
Histogram hrán v každom regióne



Histogram hrán v každom regióne

16x5 tried pre rôzne hrany

Vertikálne, horizontálne, diagonálne, „žiadne“



(a) Štyri typy smerových hrán, jedna izotropná oblasť.

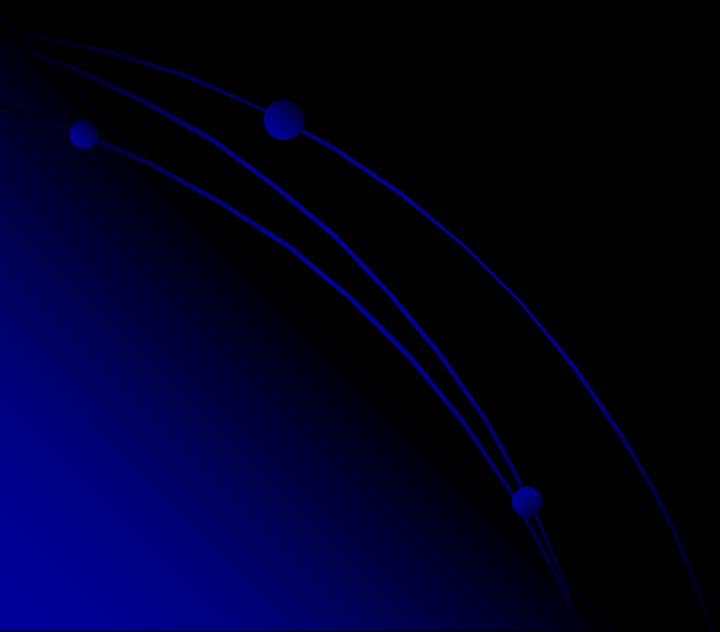
1	-1	1	1	$\sqrt{2}$	0	0	$\sqrt{2}$	2	-2
1	-1	-1	-1	0	$-\sqrt{2}$	$-\sqrt{2}$	0	-2	2

(b) Filtre zodpovedajúce typom hrán.

Color and Texture Descriptors

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IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS FOR VIDEO TECHNOLOGY,
VOL. 11, NO. 6, JUNE 2001



Čo ešte...

Hrany

Rohy

Spoje

Škvrny

Chrbáty, hrebene (v pohoriach)

Lokálne príznaky