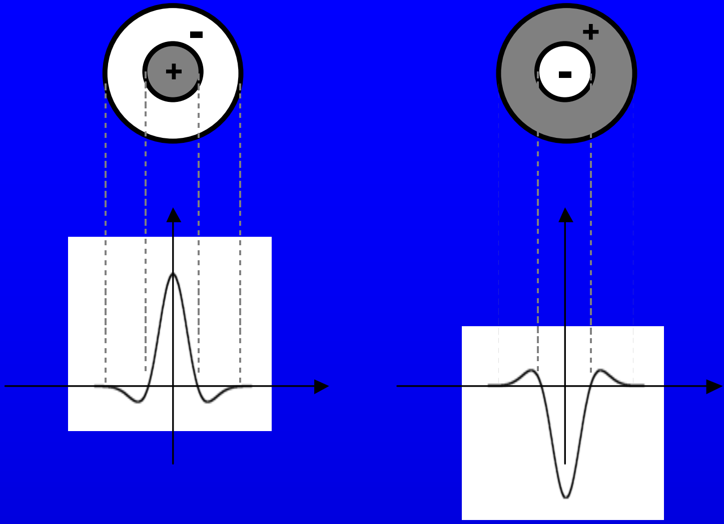
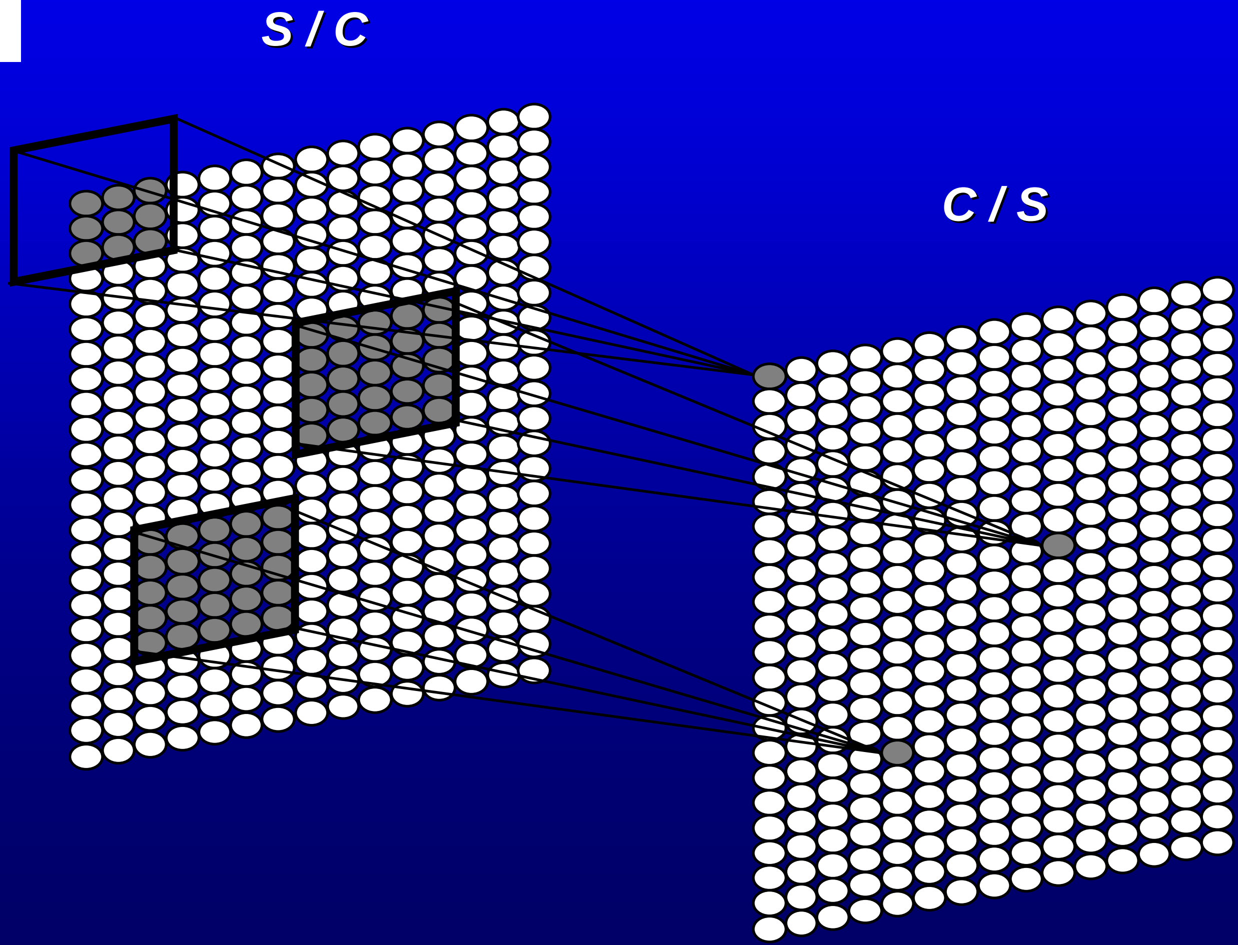
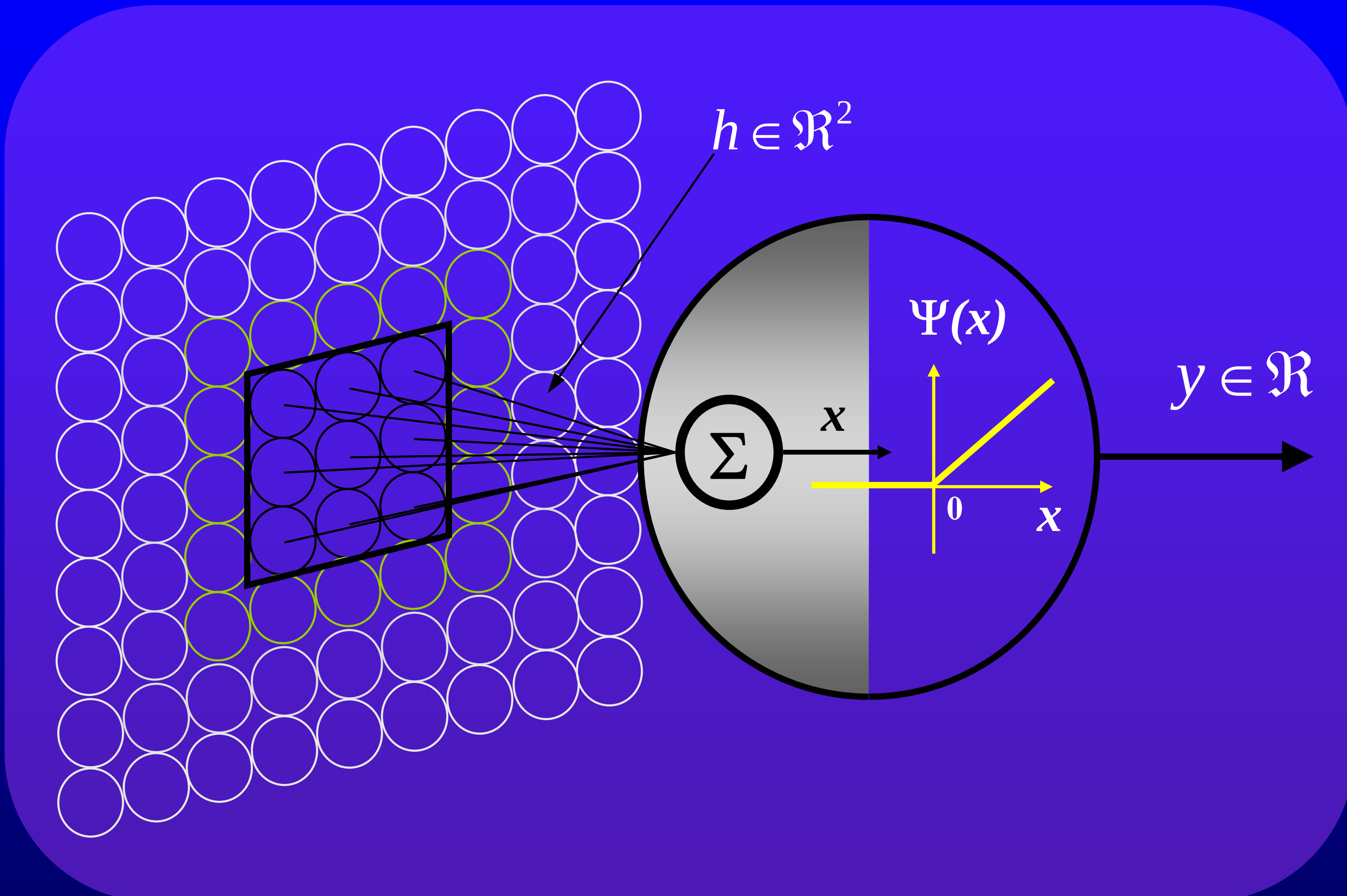
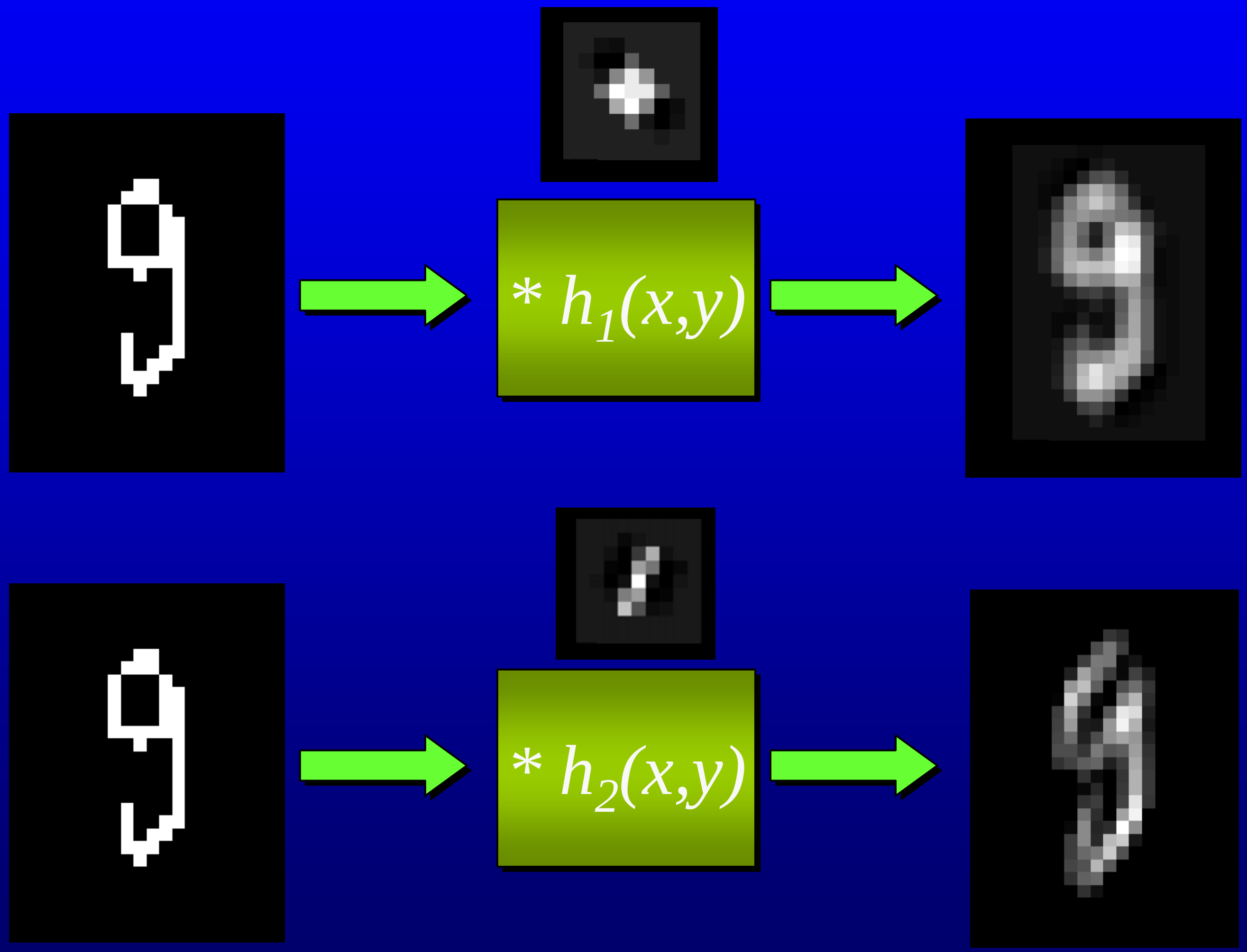

-
+
+
-


S / C
C / S

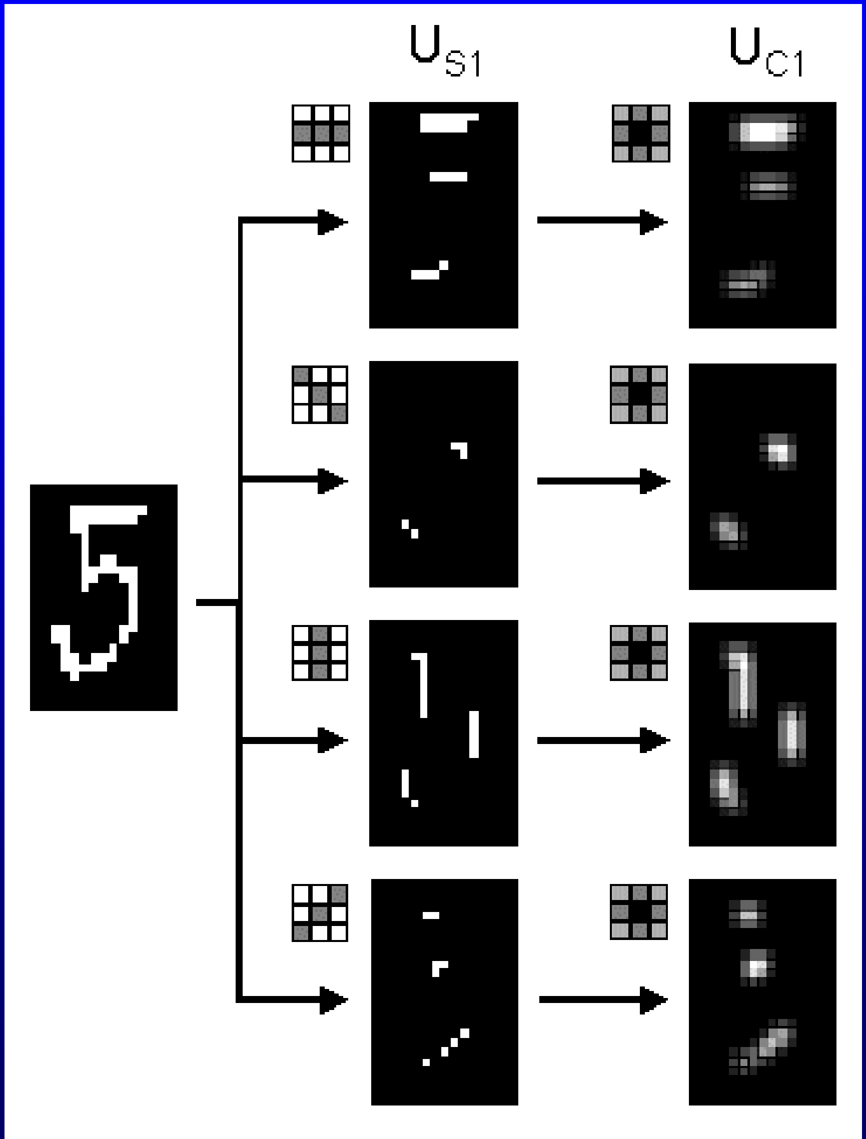


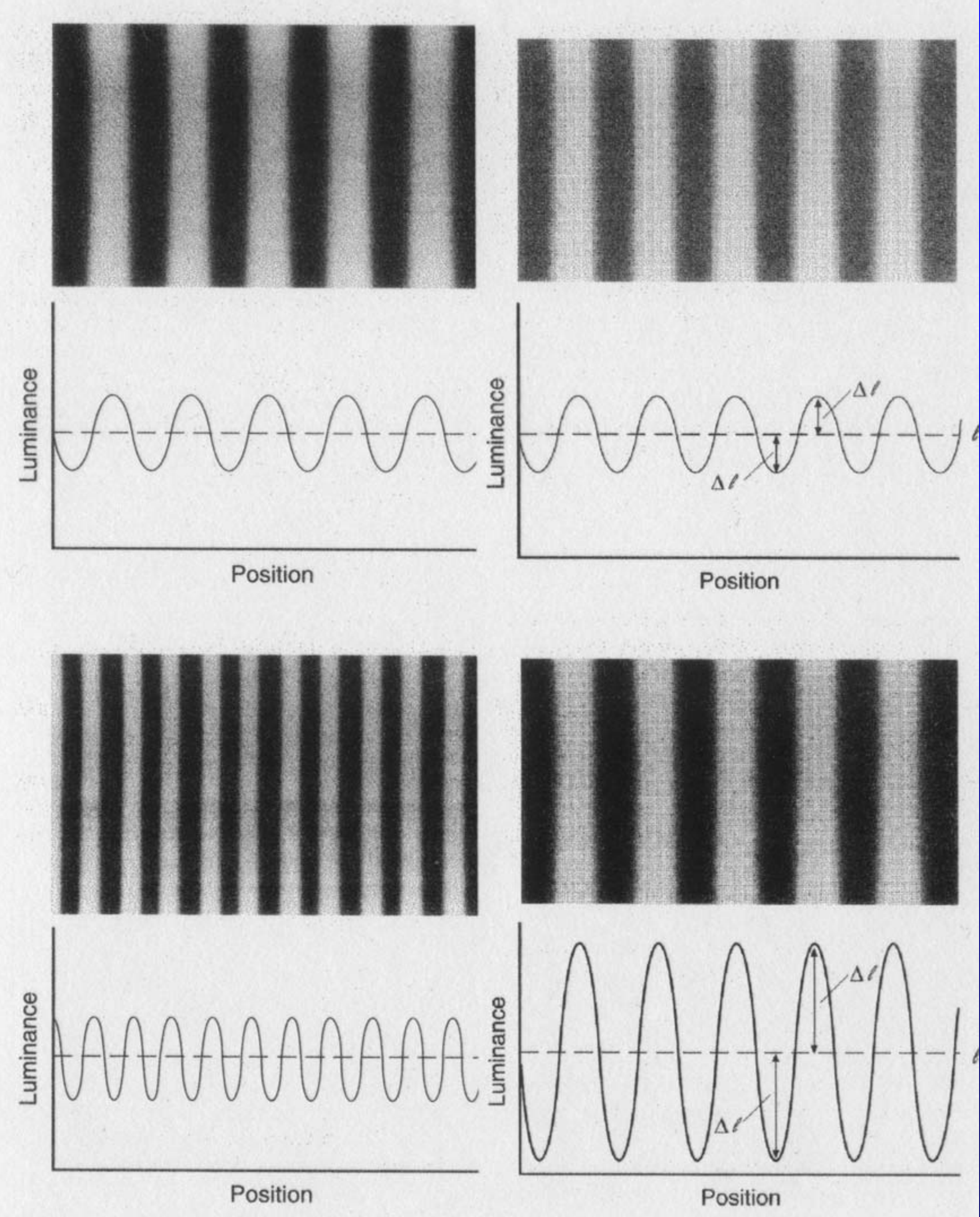
$h \in \Re^2$
Σ
x
$\Psi(x)$
0
x
$y \in \Re$

Receptive fields as filters

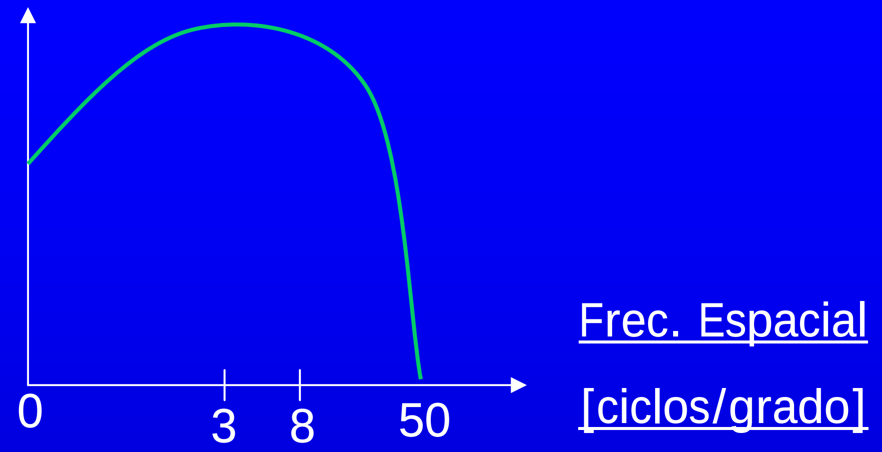


Introduction: Non-Linear Filters

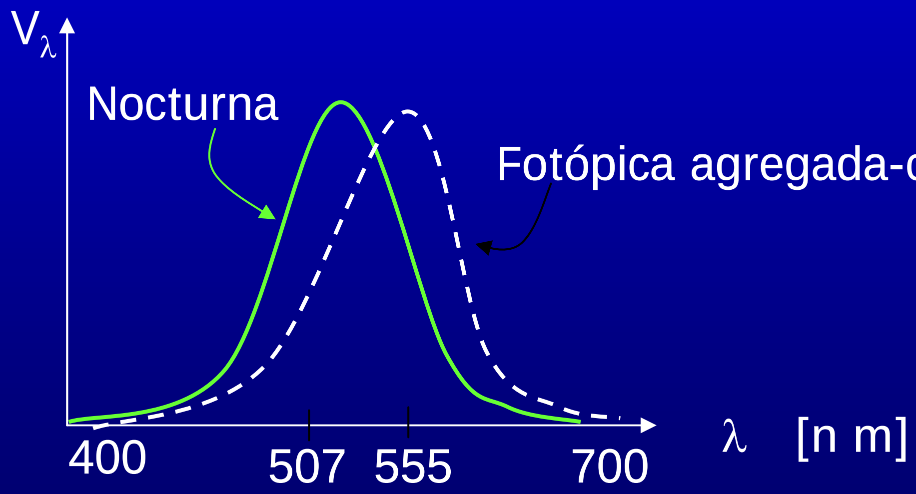



Luminance
Position
Luminance
Δℓ
Δℓ
Position
Luminance
Position
Luminance
Δℓ
Δℓ
Position

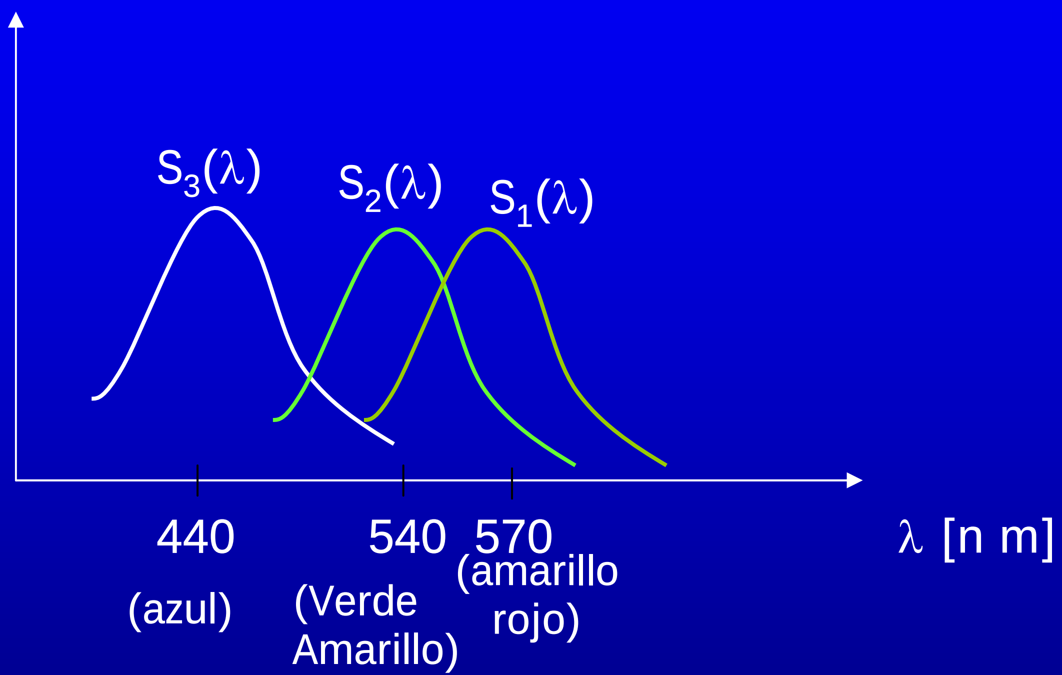
- Sensibilidad al Contraste

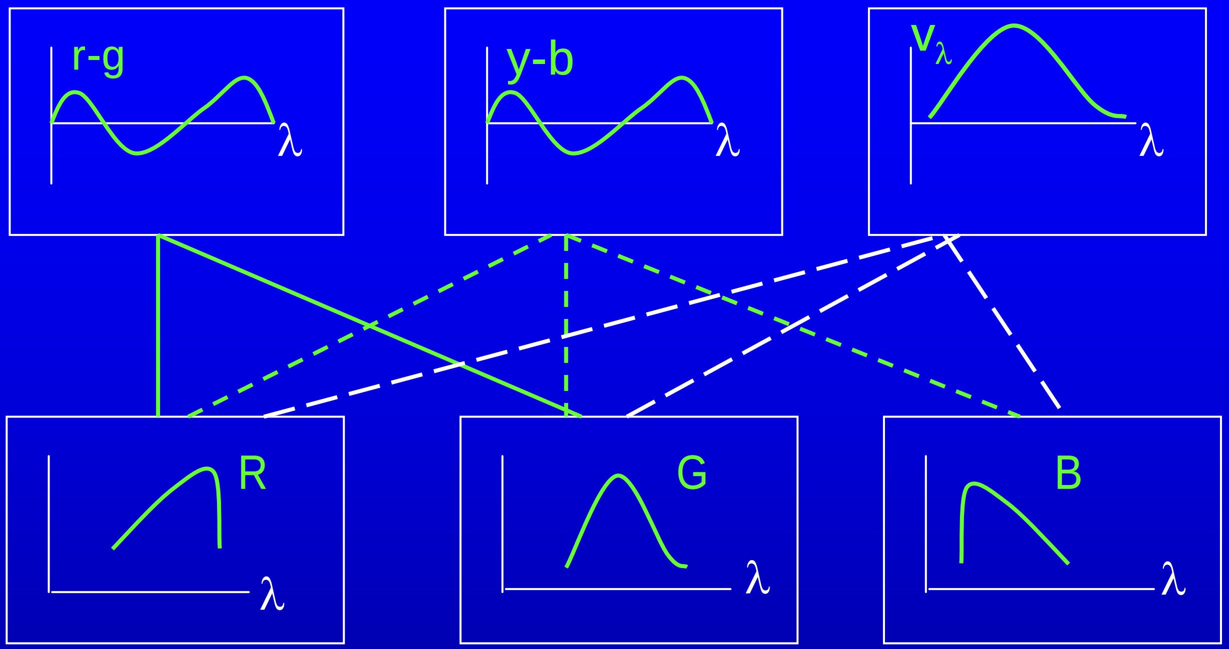


- Función eficiencia luminosa relativa

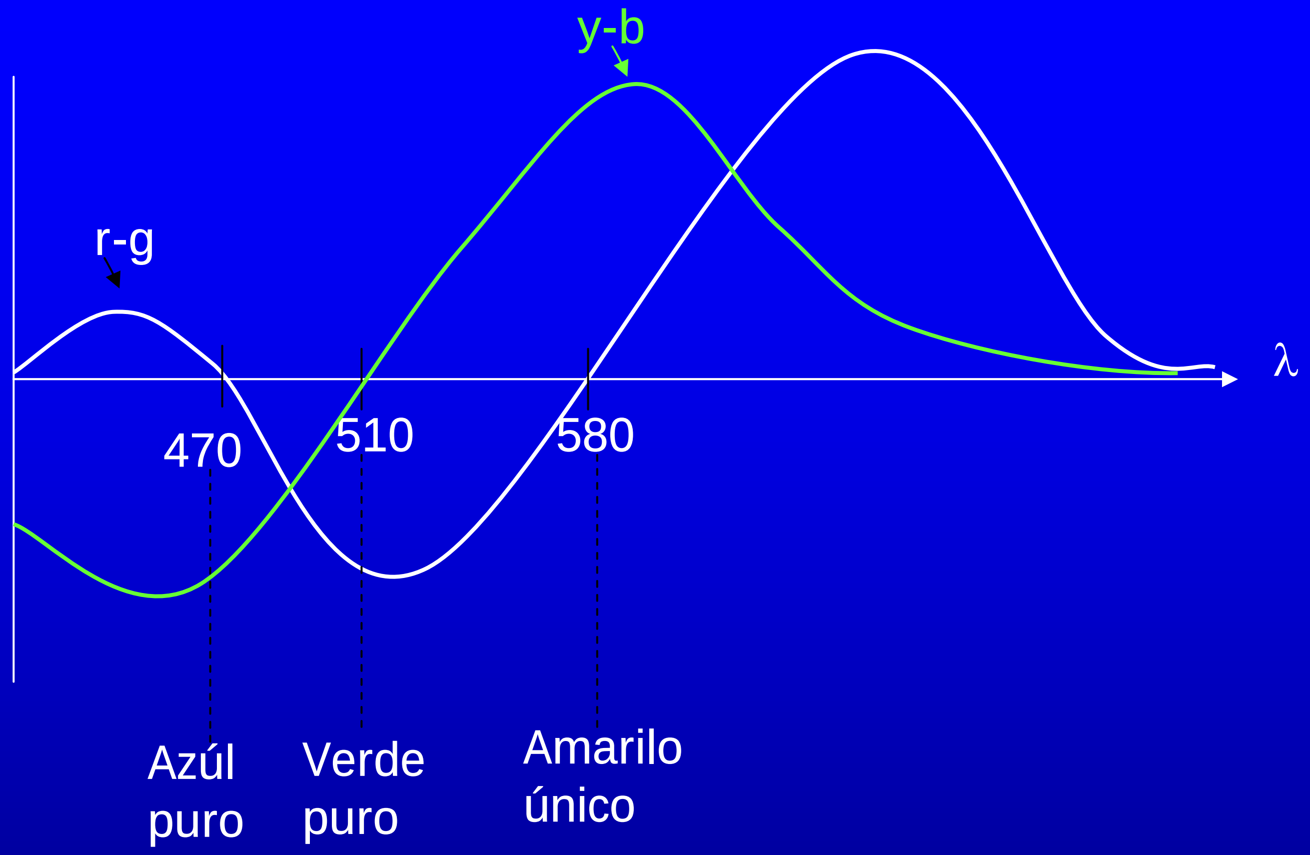


- Sensibilidad - Conos

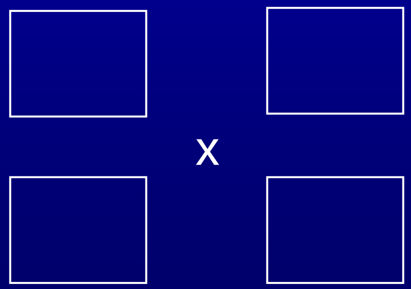


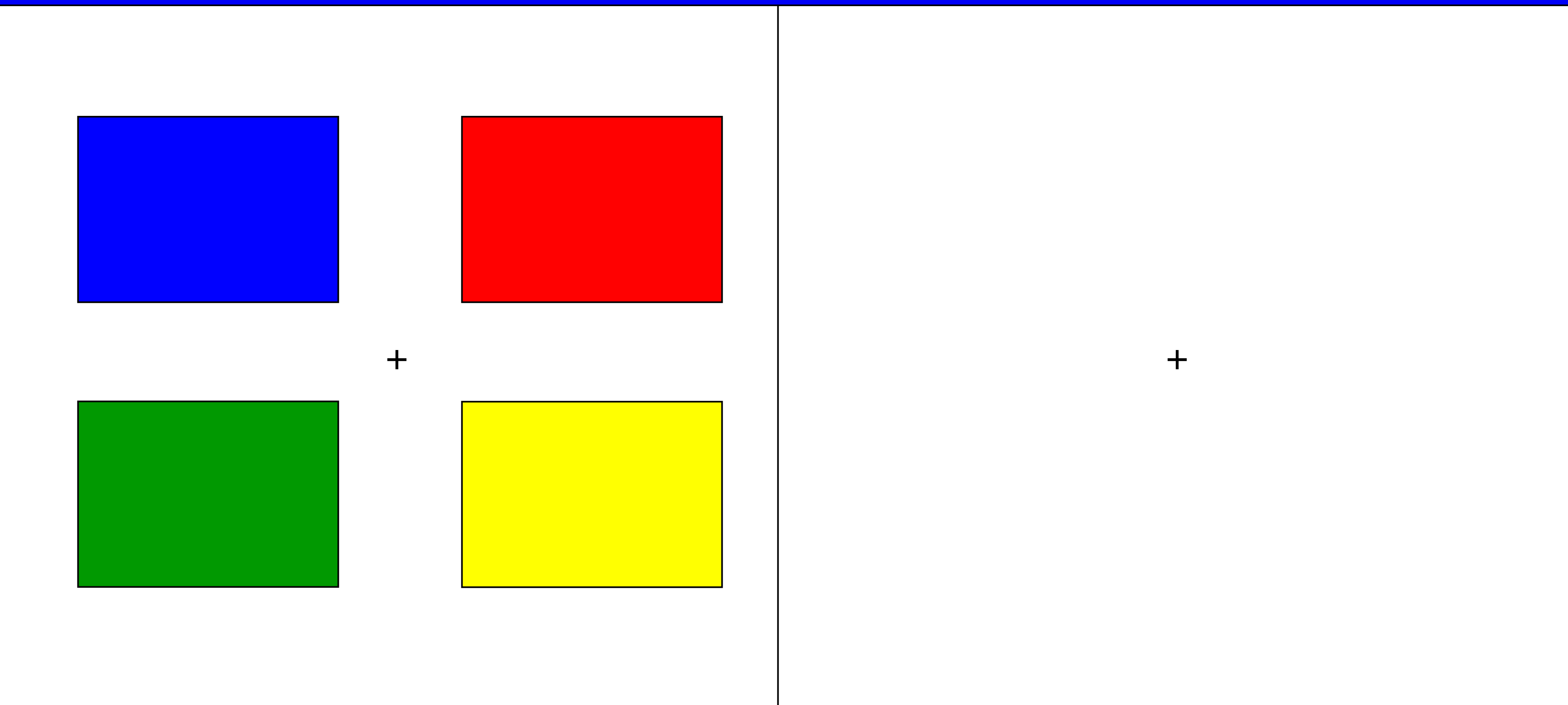


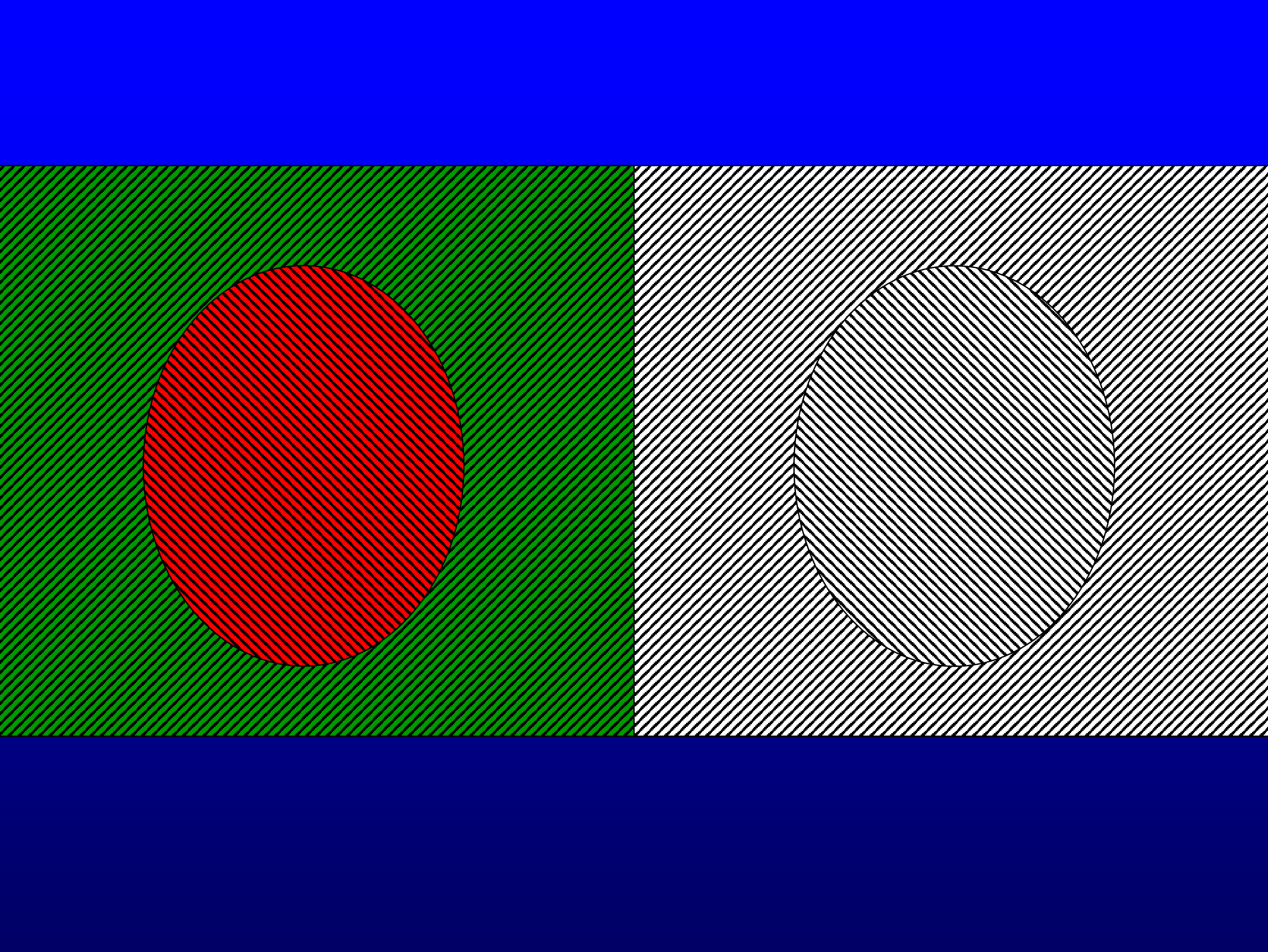
$$\begin{bmatrix} r-g \\ y-b \\ v_\lambda \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$



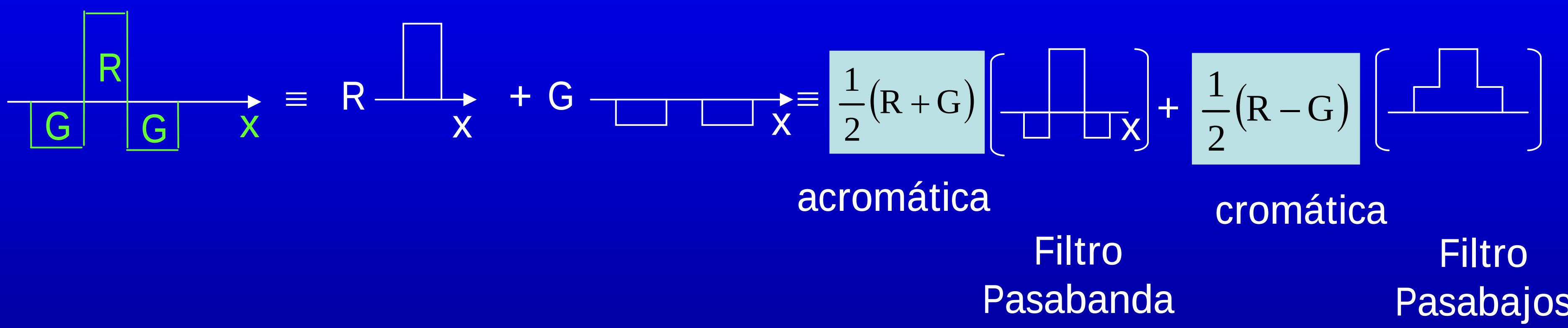
- Experimento







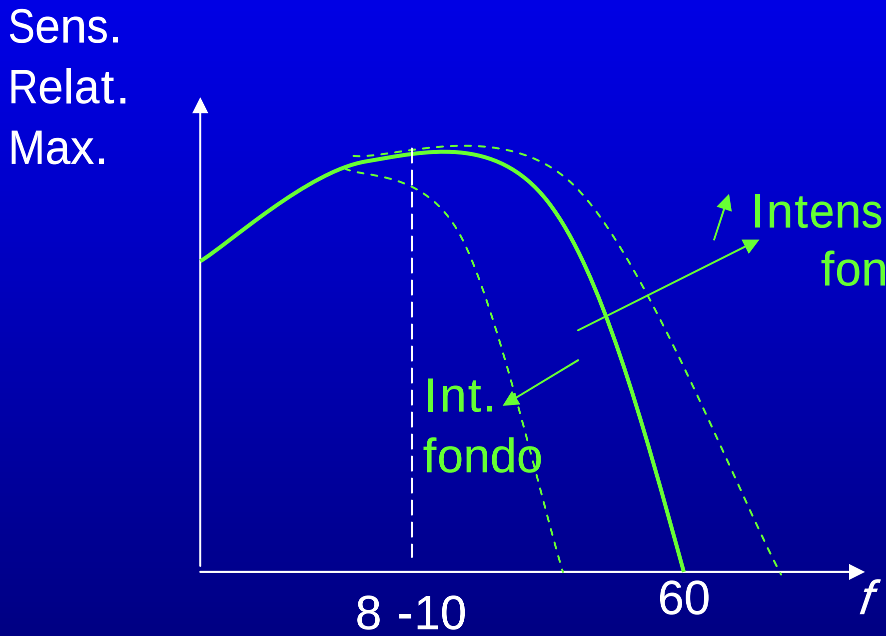
- Descomposición campo receptivo

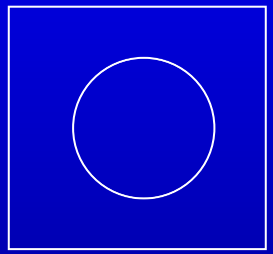


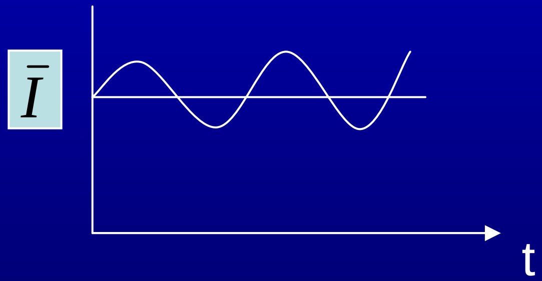
- Propiedades Temporales

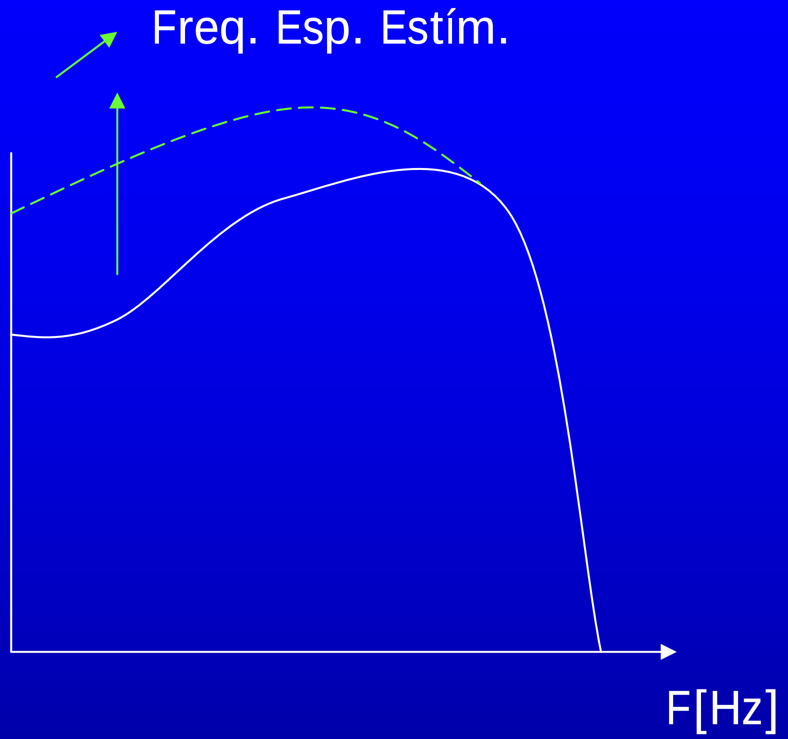
  • Frec. Crítica de Fusión

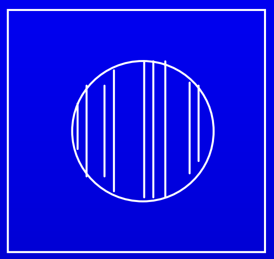
  • Función de Sensibilidad a la variación de contraste temporal

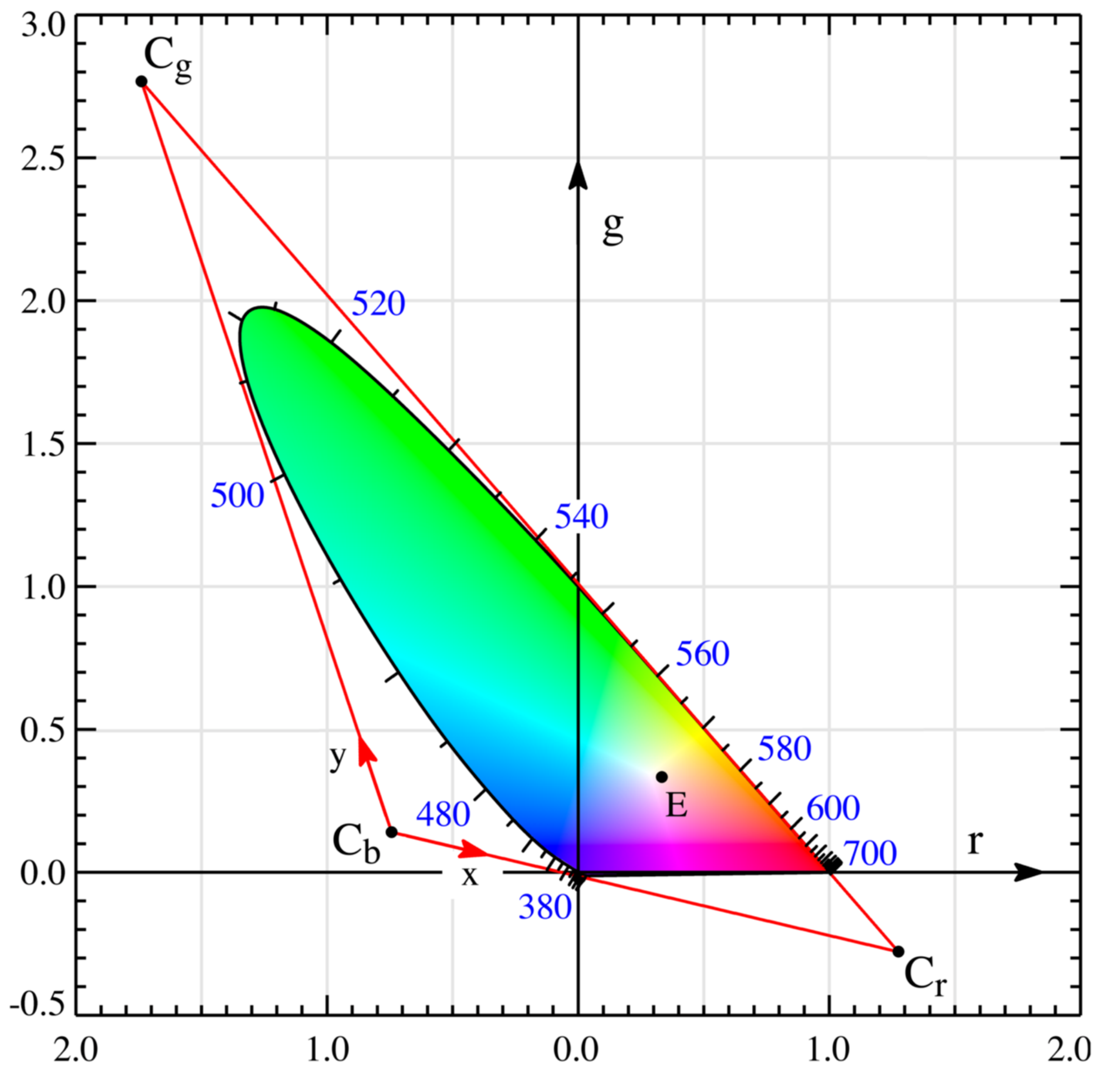







Freq. Esp. Estím.
F[Hz]





3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
2.0
1.0
0.0
1.0
2.0
C_g
C_b
C_r
g
r
x
y
E
520
500
540
560
580
600
700
480
380

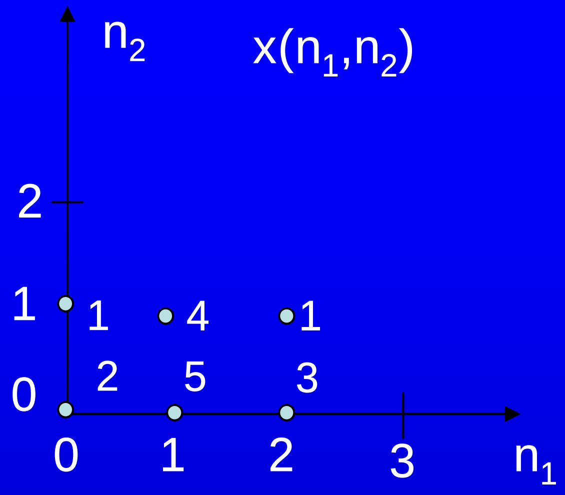
Señales 2-D

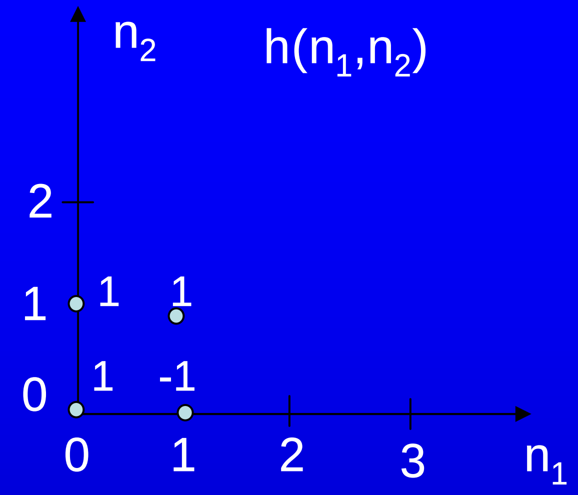
- Secuencia 2-D

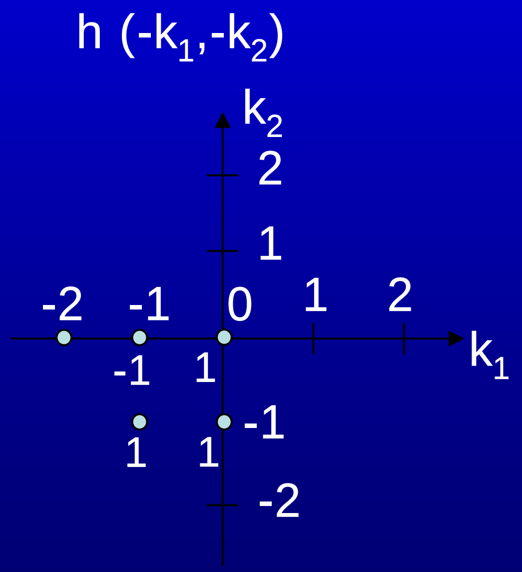
$$\delta(n_1, n_2)$$
$$u(n_1, n_2)$$

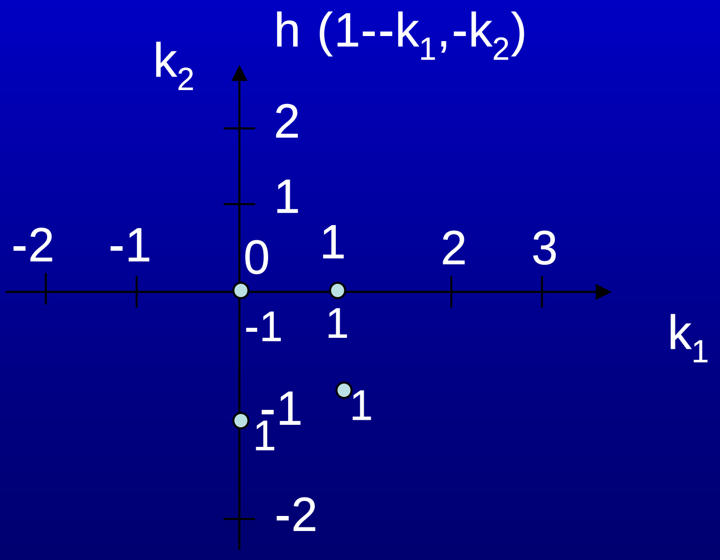
- Convolución 2-D

$$y(n_1, n_2) = x(n_1, n_2) * h(n_1, n_2) = \sum_{k_1} \sum_{k_2} x(k_1, k_2) h(n_1 - k_1, n_2 - k_2)$$


x(n_1,n_2)
n_2
n_1
2
1
0
0
1
2
3
1
4
1
2
5
3

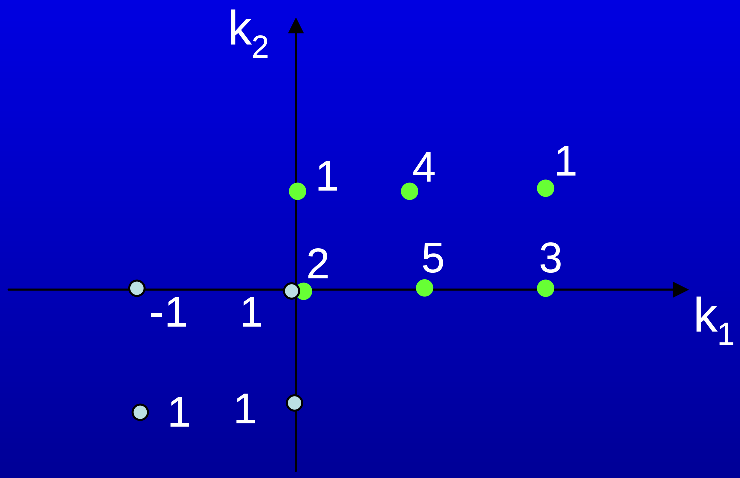

h(n_1,n_2)
n_2
n_1
2
1
0
0
1
2
3
1
1
1
-1


h (-k_1,-k_2)
k_2
k_1
2
1
-2
-1
0
1
2
-1
1
-1
1
1
-2

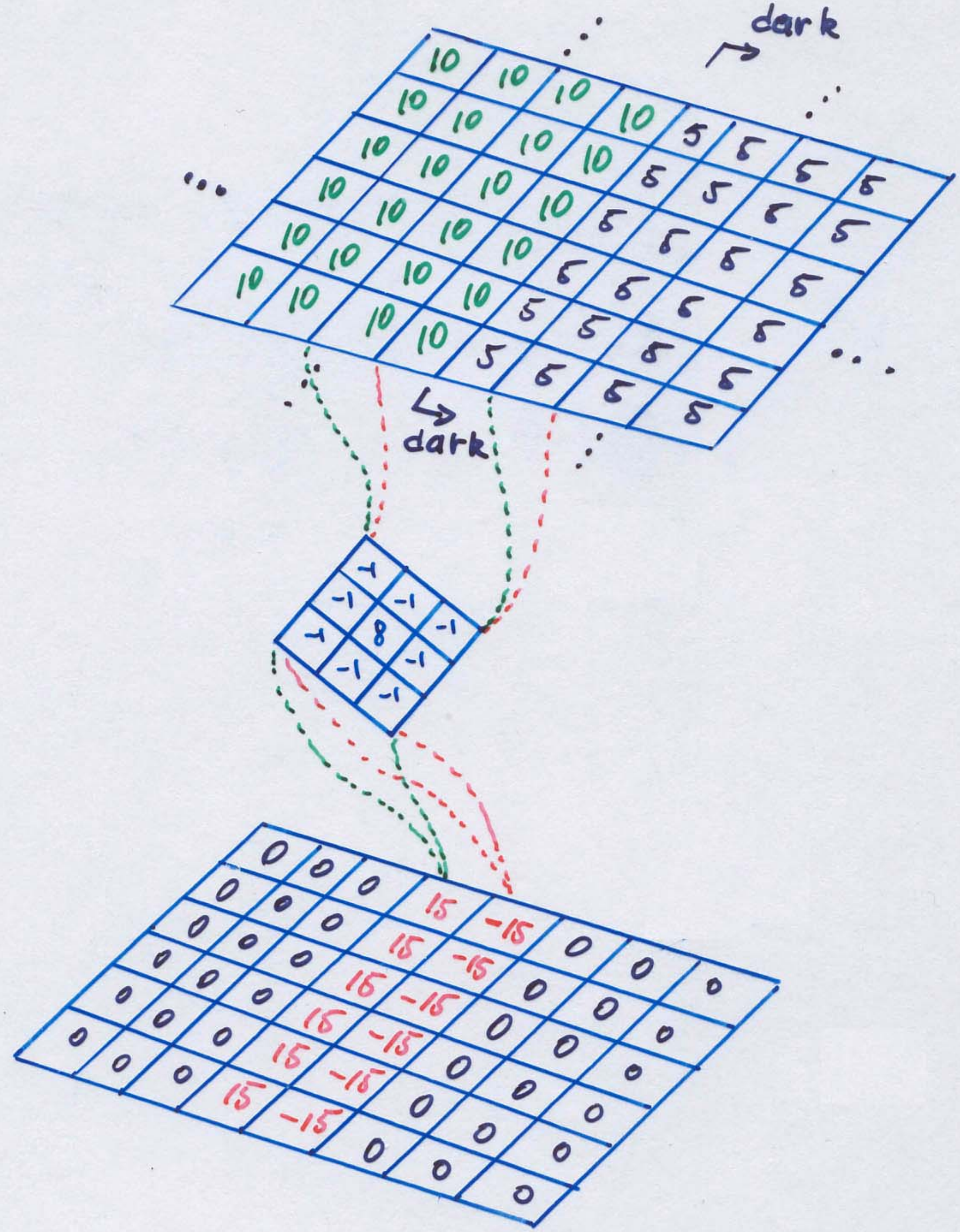

h (1--k_1,-k_2)
k_2
k_1
2
1
-2
-1
0
1
2
3
-1
1
-1
1
1
-2

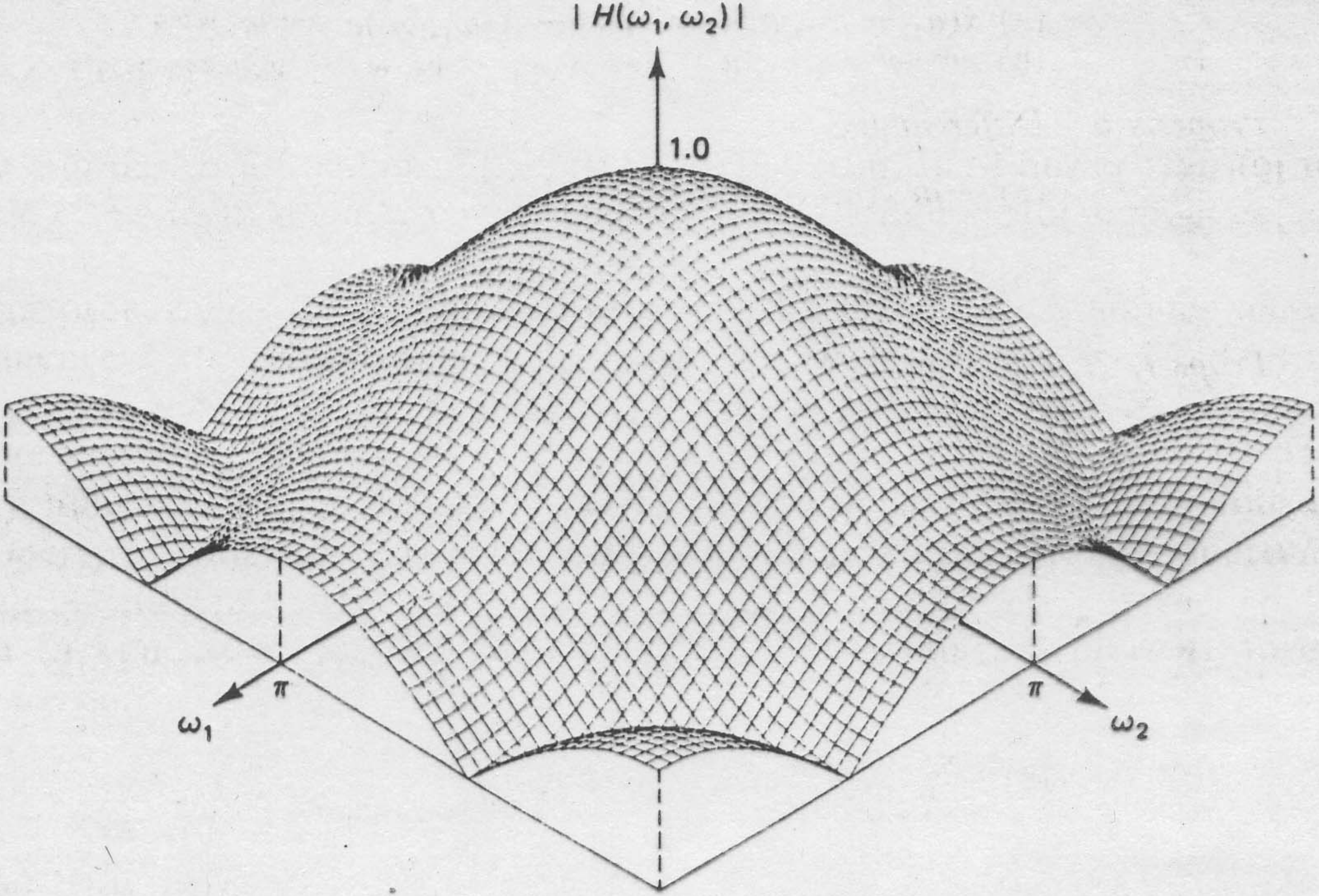
$$n_1 = n_2 = 0$$

$$y(0,0) = \sum_{k_1} \sum_{k_2} (-k_1, -k_2) x(k_1, k_2)$$

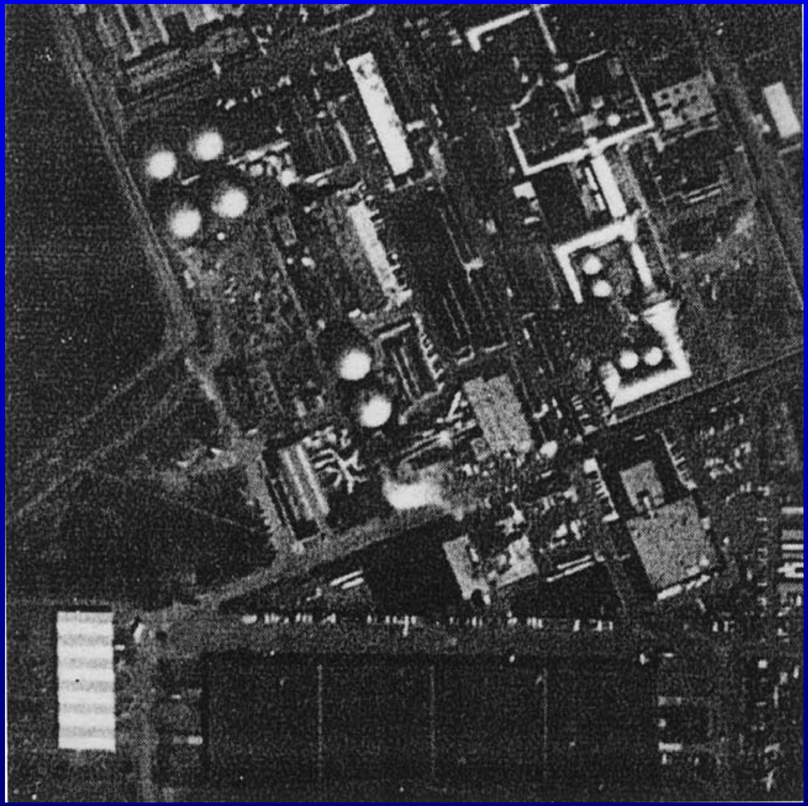
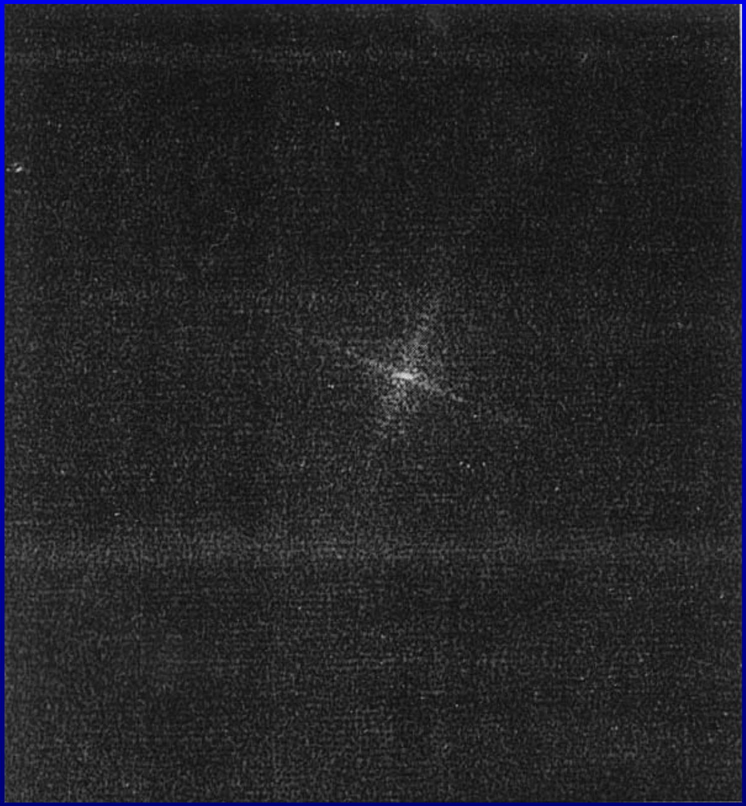


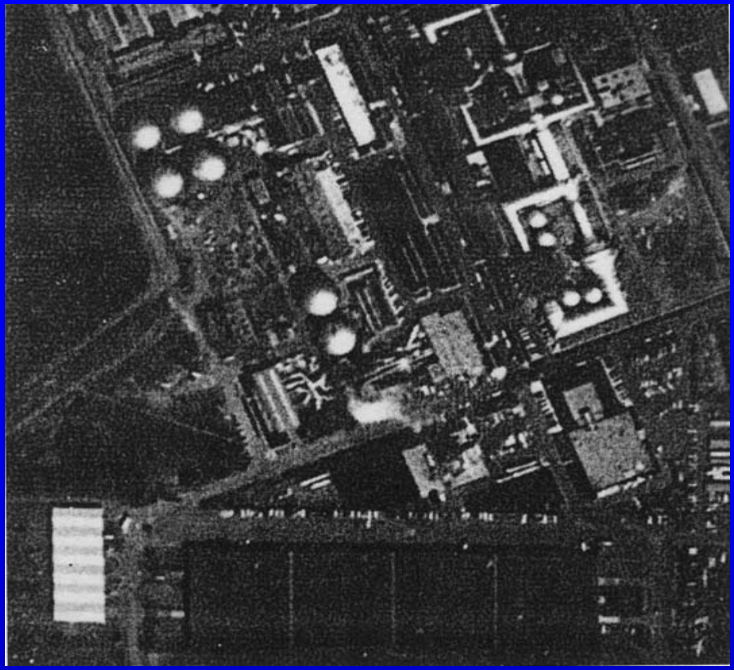
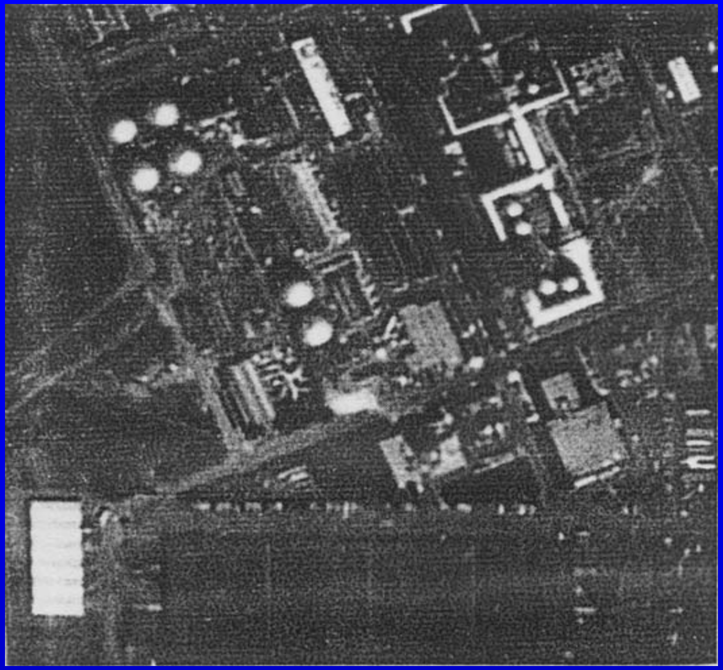
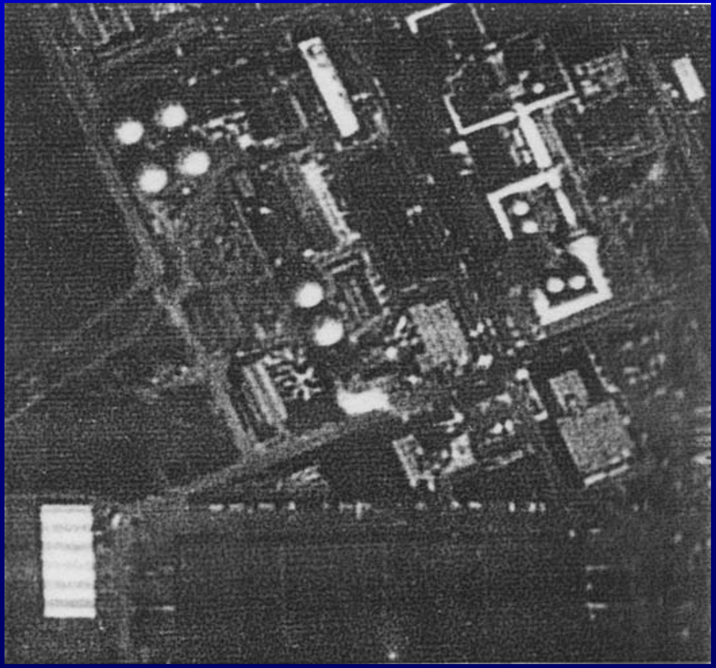
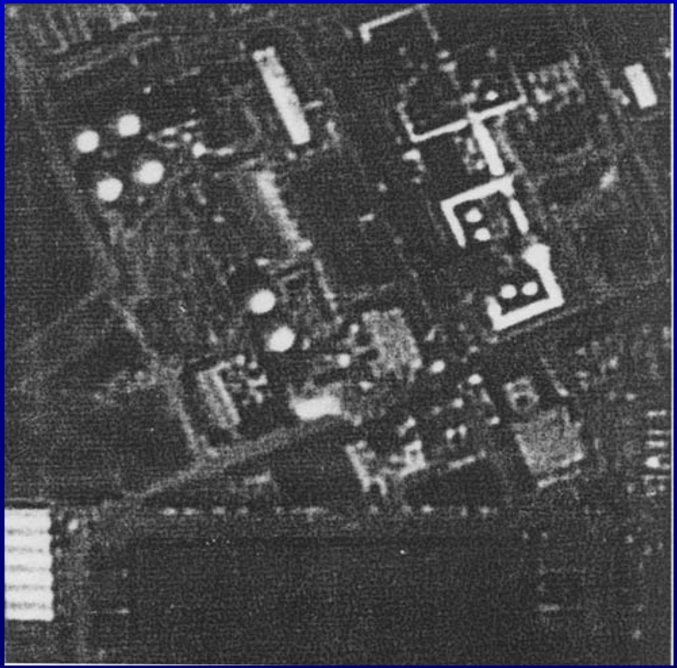
Y (0,0) = 1·2 = 2

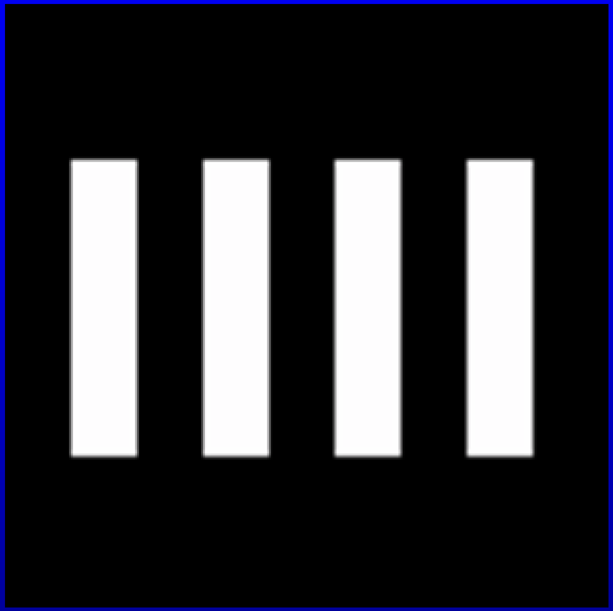

dark
dark



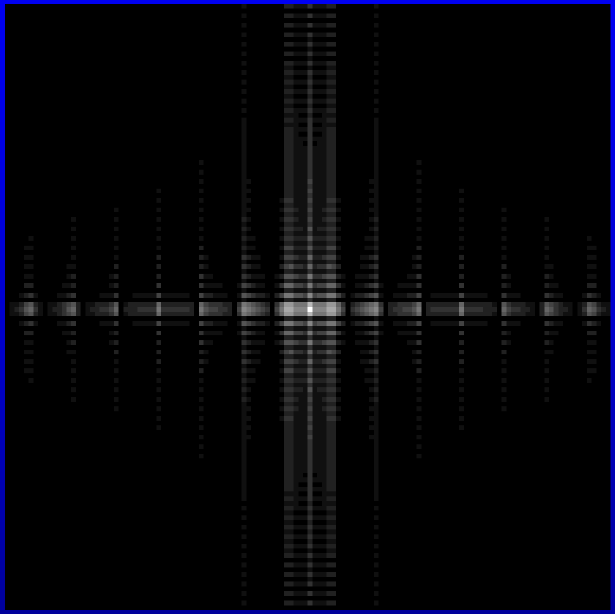
$|H(\omega_1, \omega_2)|$
1.0
π
ω_1
π
ω_2

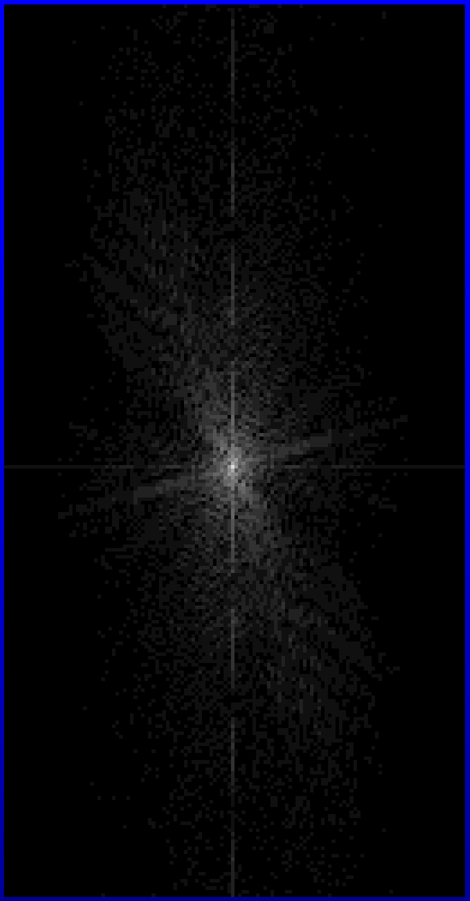







plano (n_1, n_2)

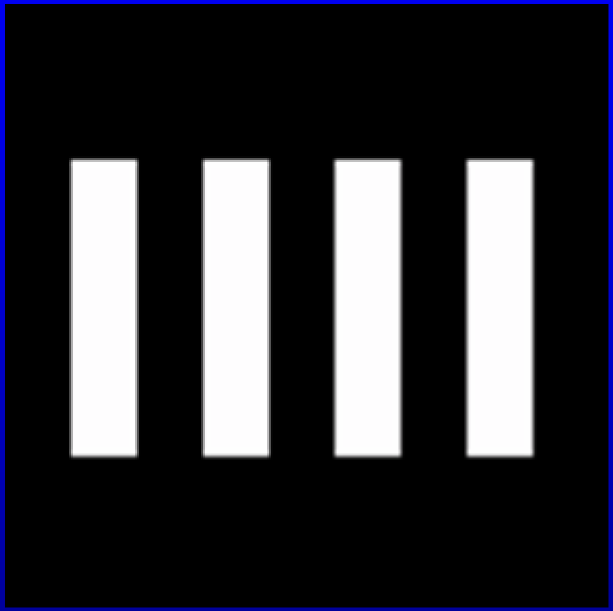


plano (k_1, k_2)

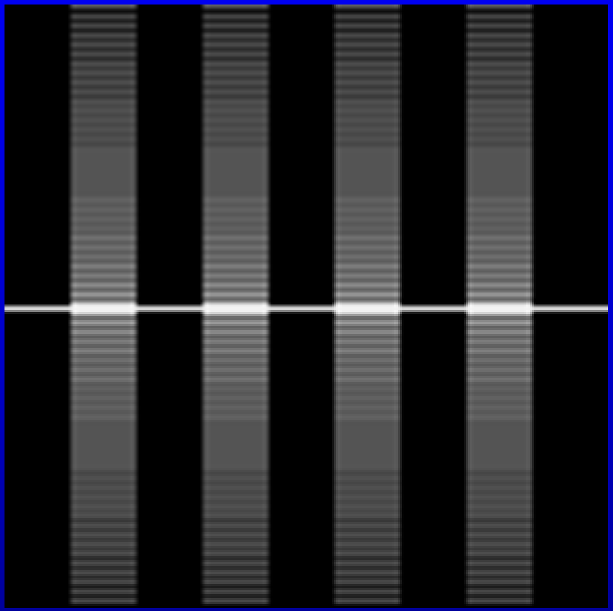


plano (n_1, n_2)

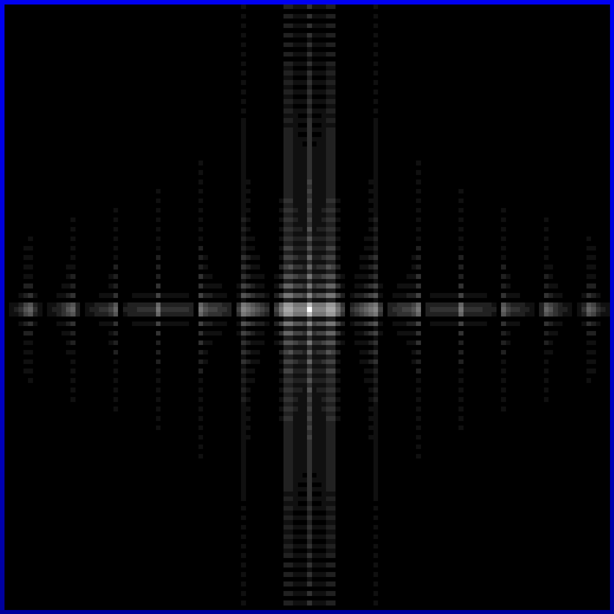
plano (k_1, k_2)



plano (n_1, n_2)

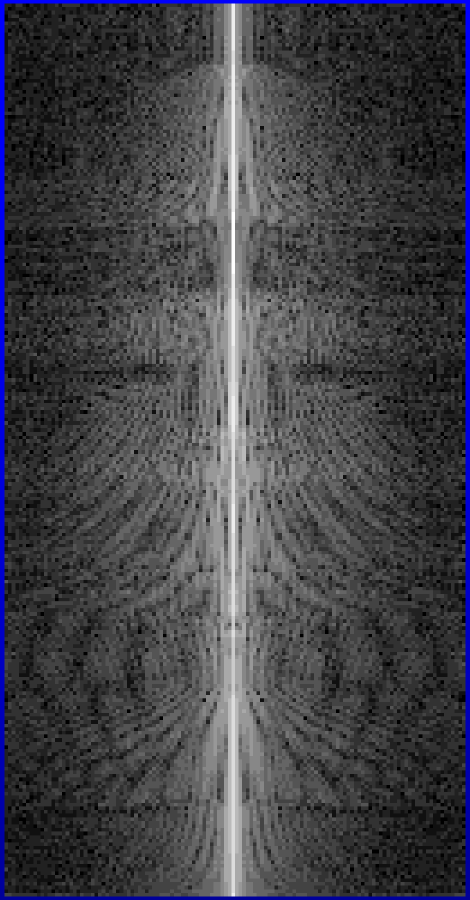


plano (k_1, n_2)

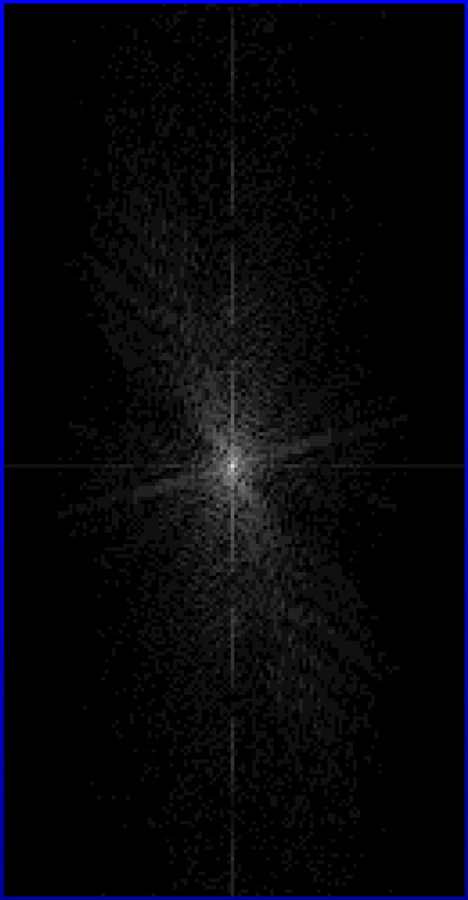


plano (k_1, k_2)

plano (n_1, n_2)

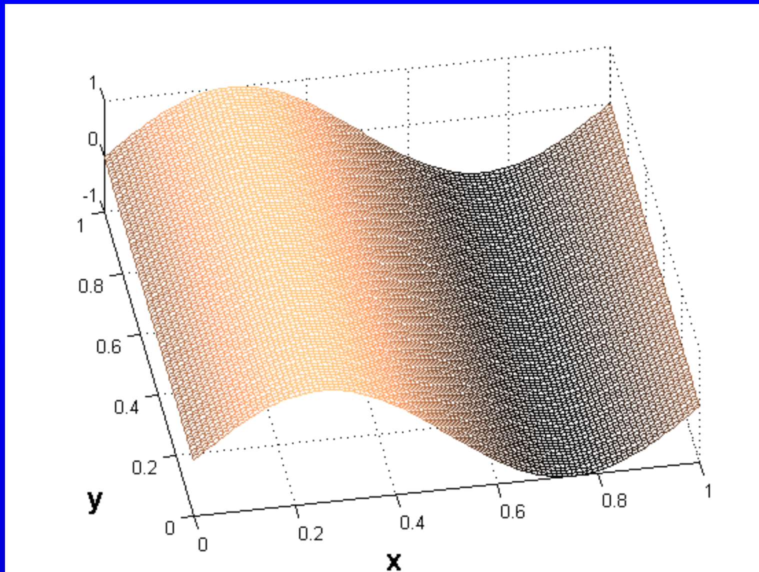


plano (k_1, n_2)

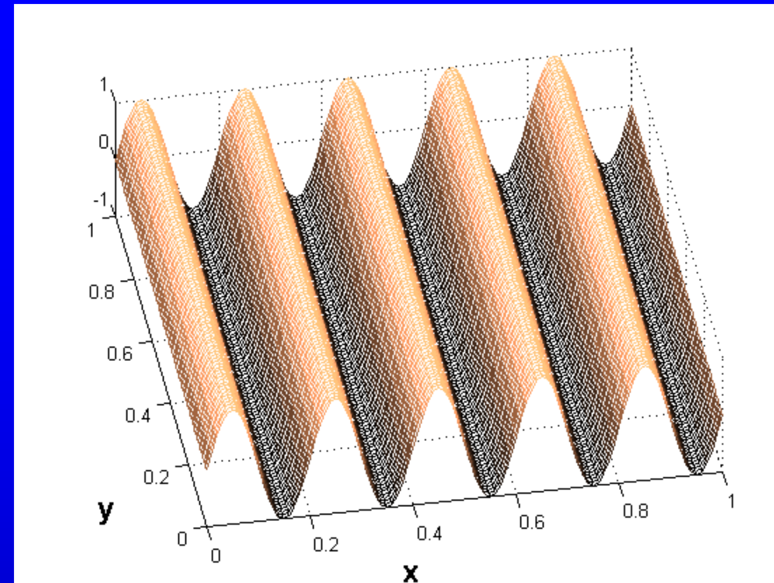


plano (k_1, k_2)

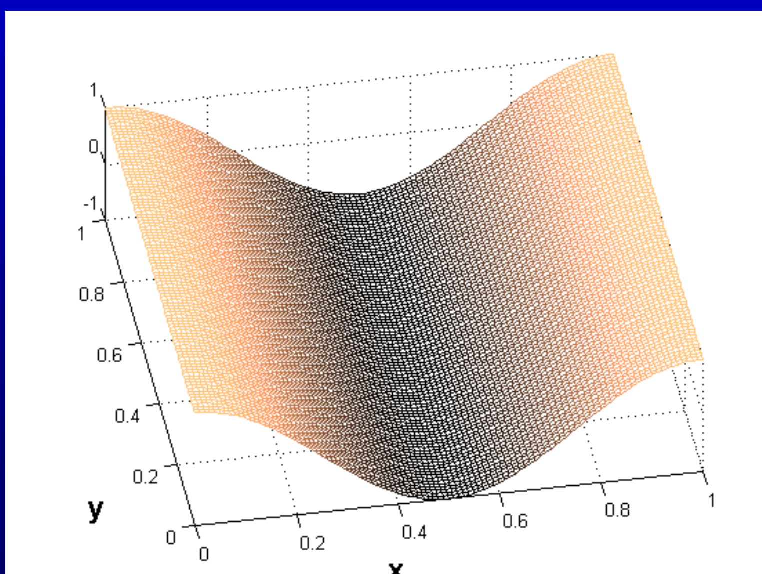
$N_1=N_2$	$(N_1\ N_2\ )^2$ (DFT Directa)	$N_2(N_1\ )^2+N_1(N_2)^2$ (DFT, Des. Fila-Columna)	$N_1\ N_2\ \log_2(N_1N_2)$ (FFT, Des. Fila-Columna)
8	4096	1024	35
32	1048576	65536	928
128	268435456	4194304	20786
256	4294967296	33554432	95021
512	68719476740	268435456	427595



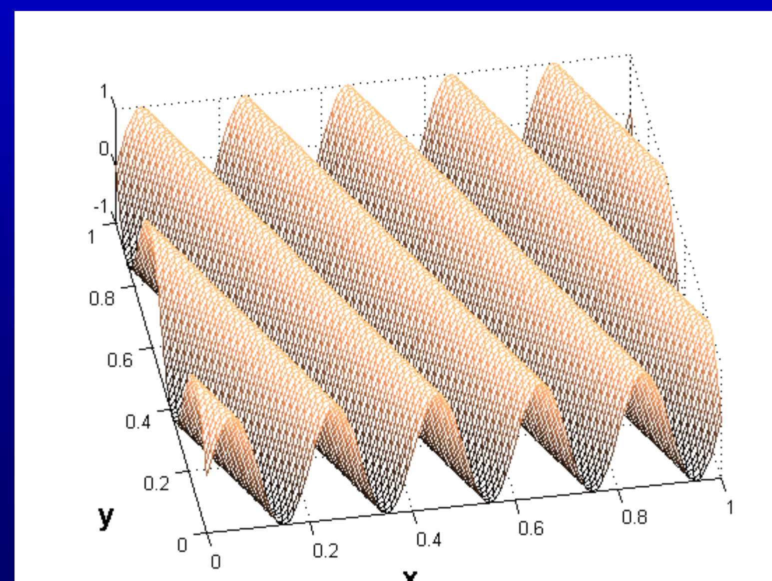
sen(2*π*x)



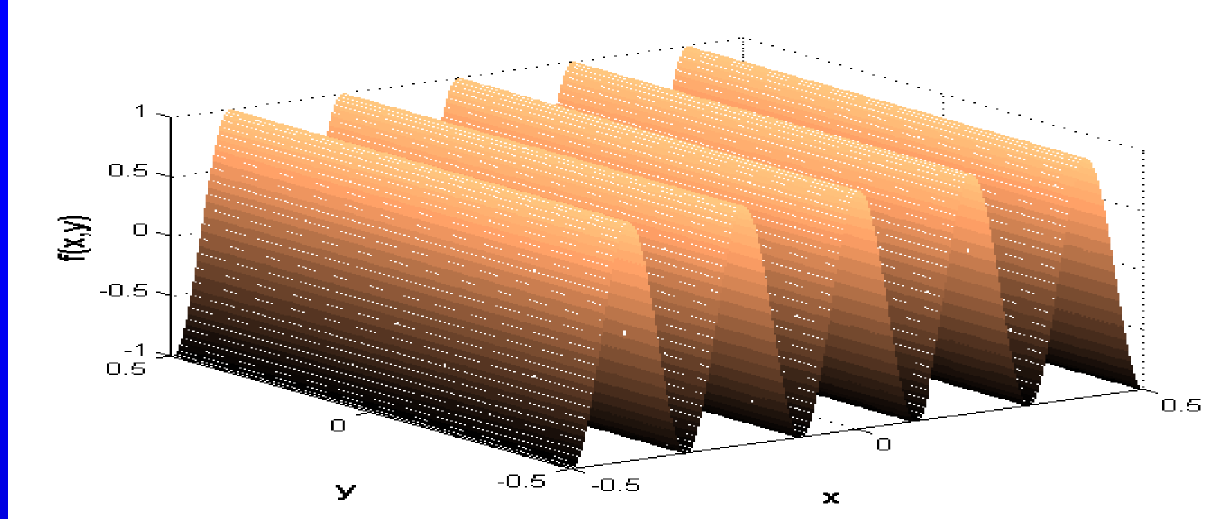
sen(10*π*x)



cos(2*π*x)



sen(10*π*x +4*pi*y)

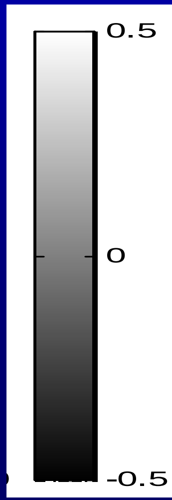


$f(x,y) = \cos(10\pi x)*1$

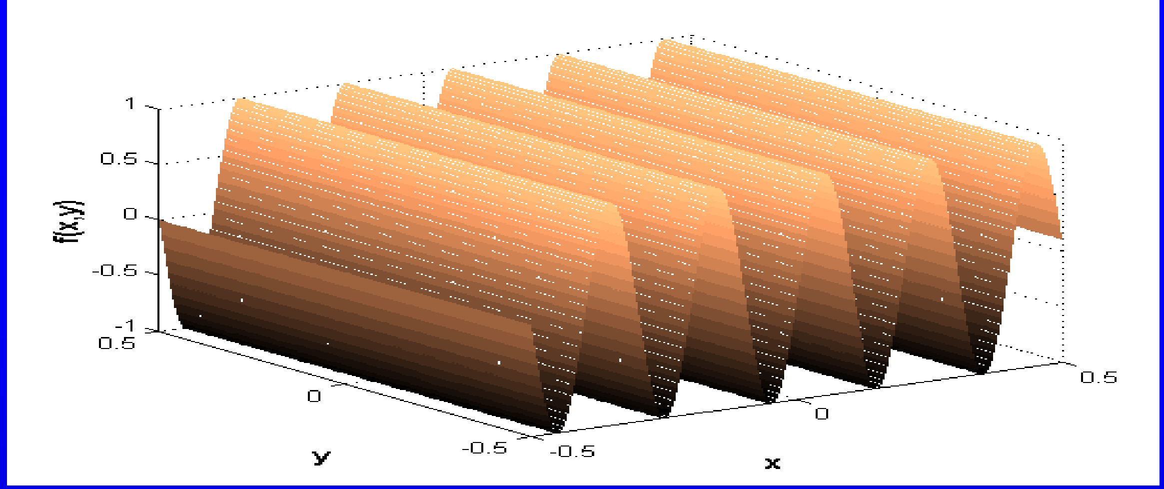
Fourier Transform

$F(u,v) = 1/2\ [\delta(u+5,0) + \delta(u-5,0)]$

Real [F(u,v)]



Imaginary [F(u,v)]

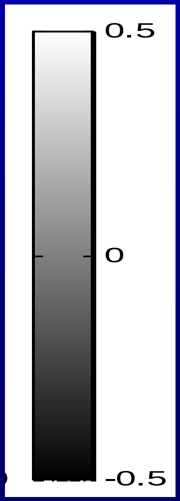


$f(x,y) = \text{sen}(10\pi x)$

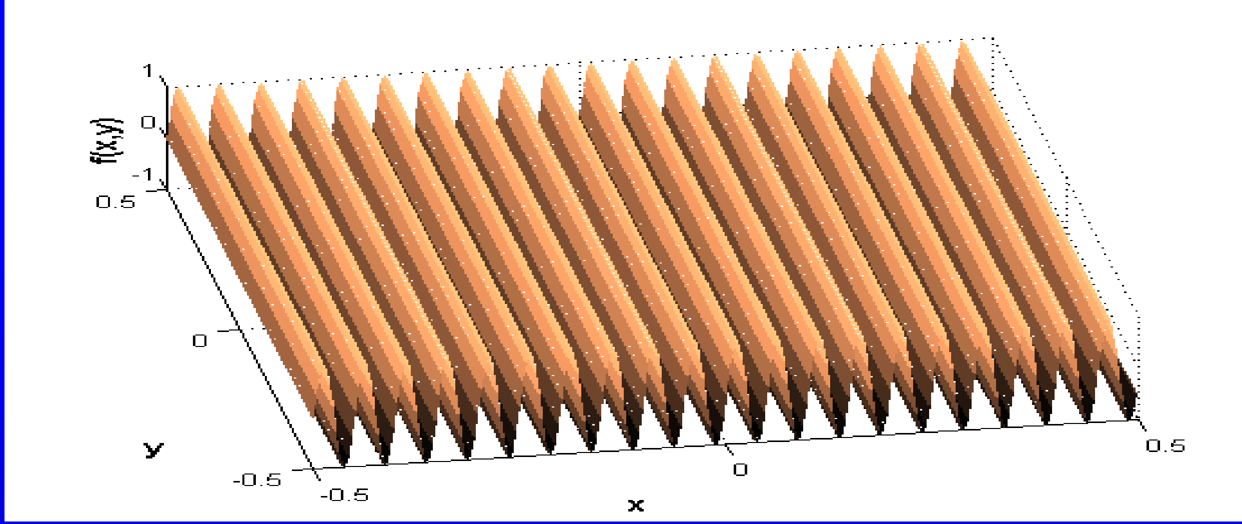
Fourier Transform

$F(u,v) = i/2\ [\delta(u+5,0) - \delta(u-5,0)]$

Real [F(u,v)]



Imaginary [F(u,v)]

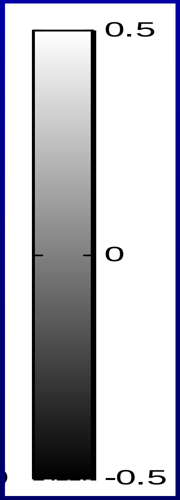


$f(x,y) = \text{sen}(40\pi x)$

Fourier Transform

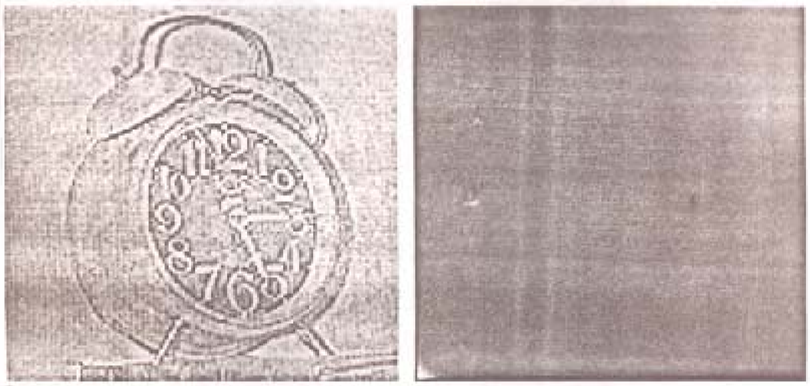
$F(u,v) = i/2\ [\delta(u+20,0) - \delta(u-20,0)]$

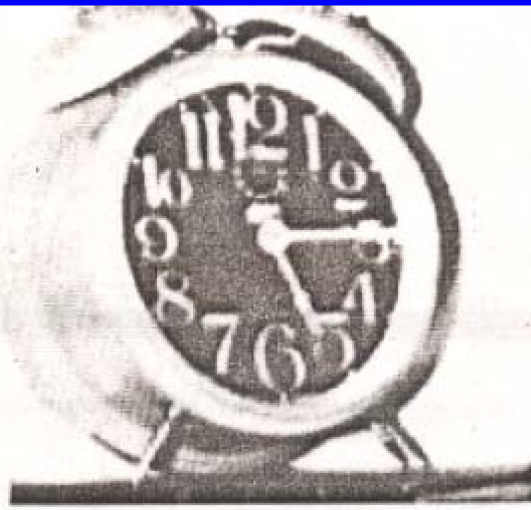
Real [F(u,v)]



Imaginary [F(u,v)]

(a)



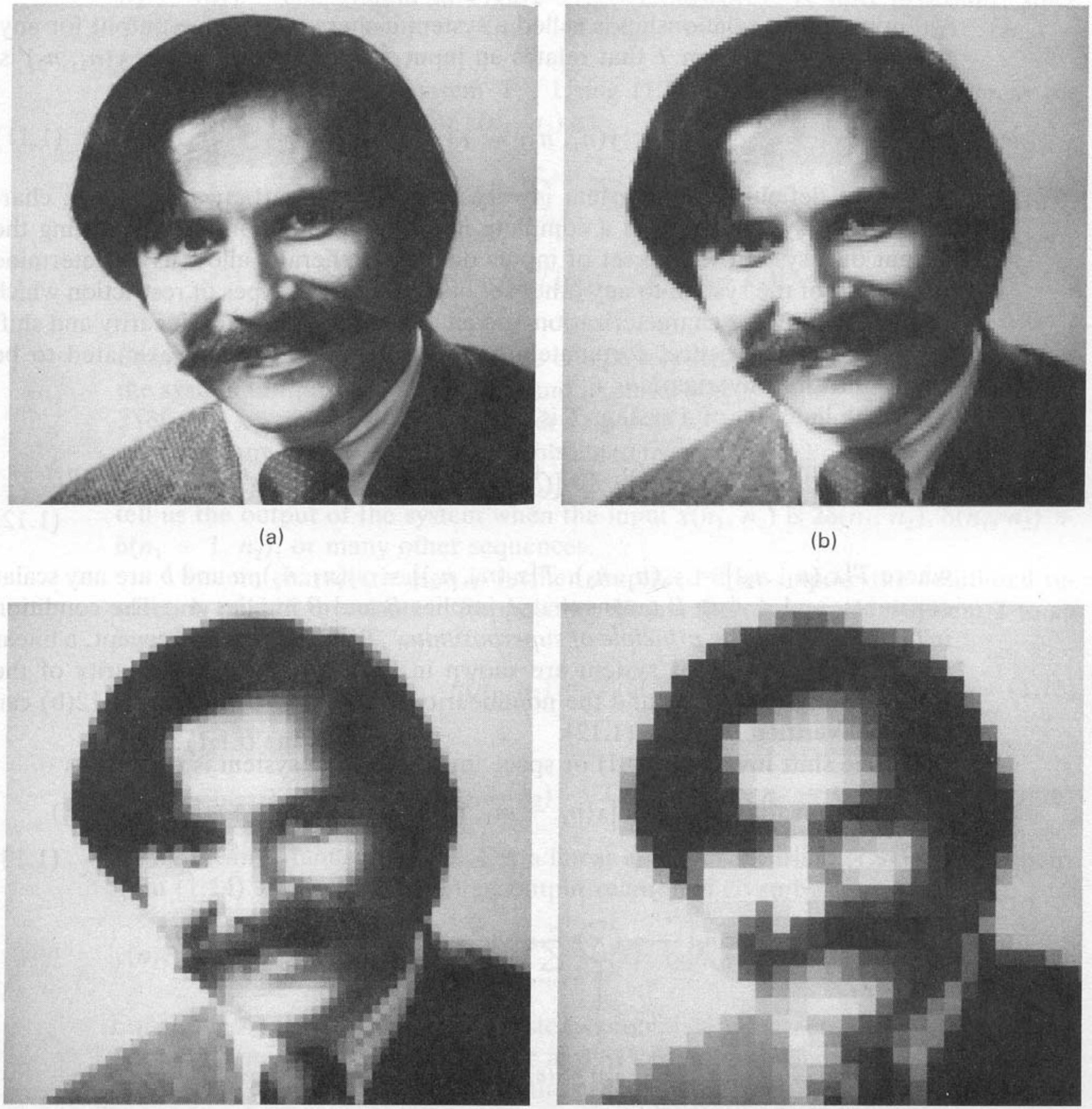


(a)

(b)

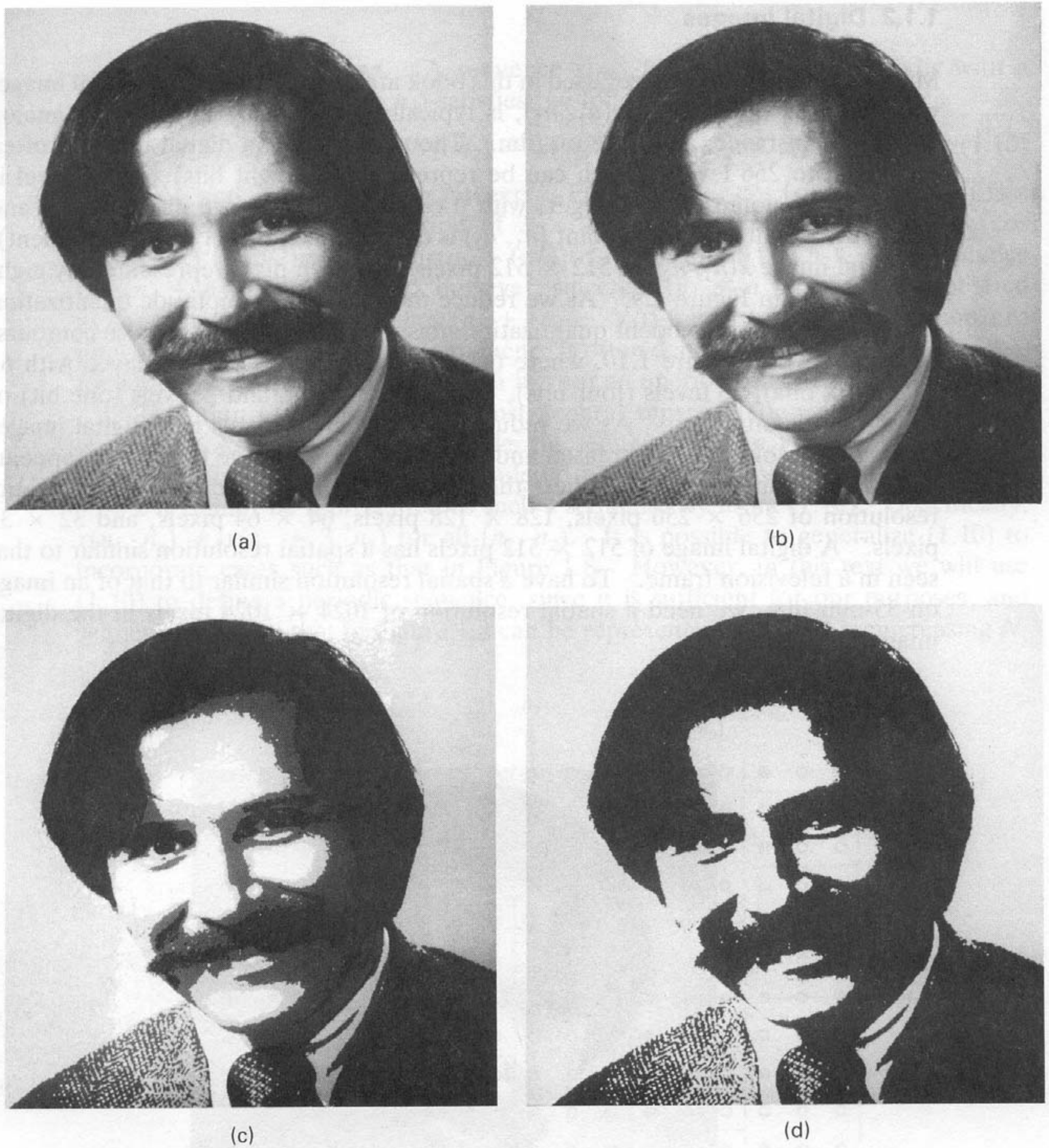
(a)

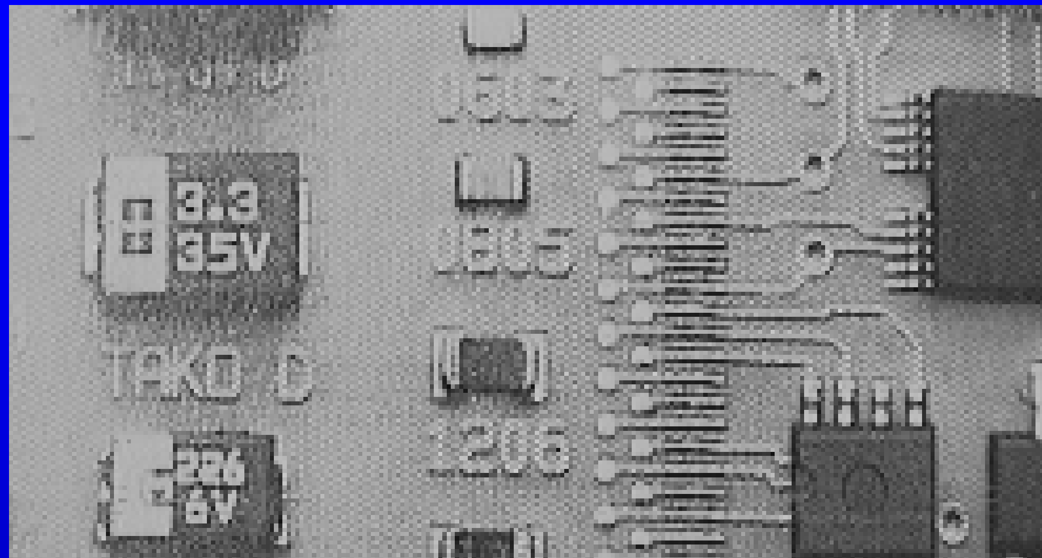
(b)

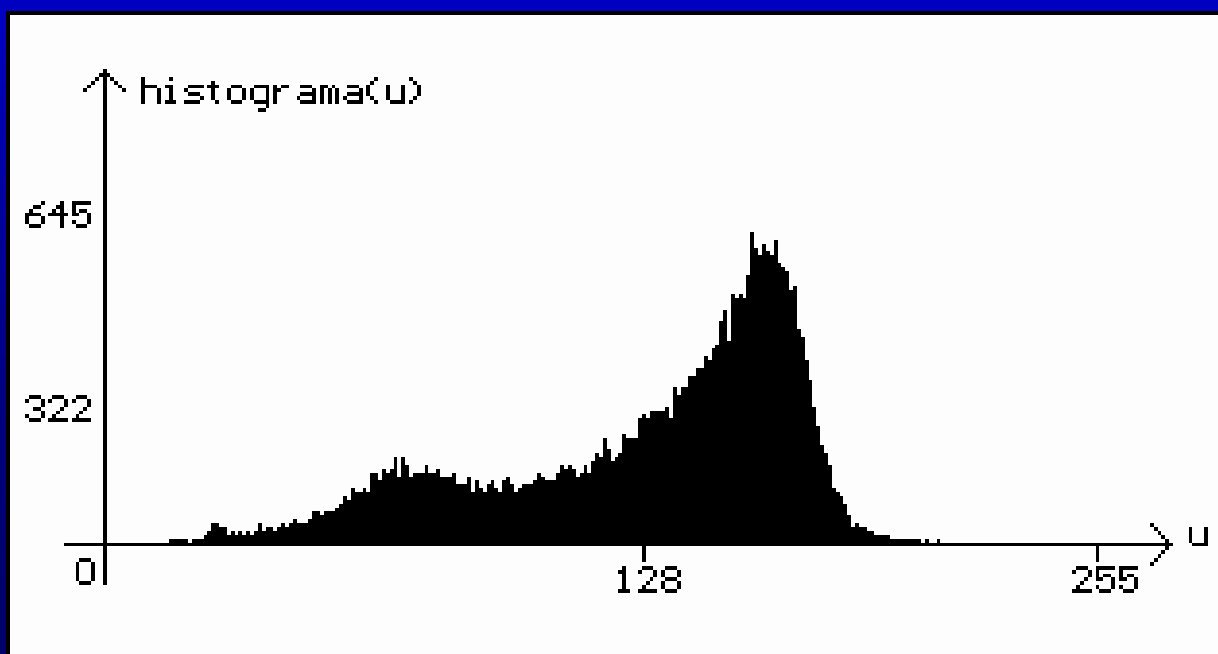


(a) (b)

(c) (d)

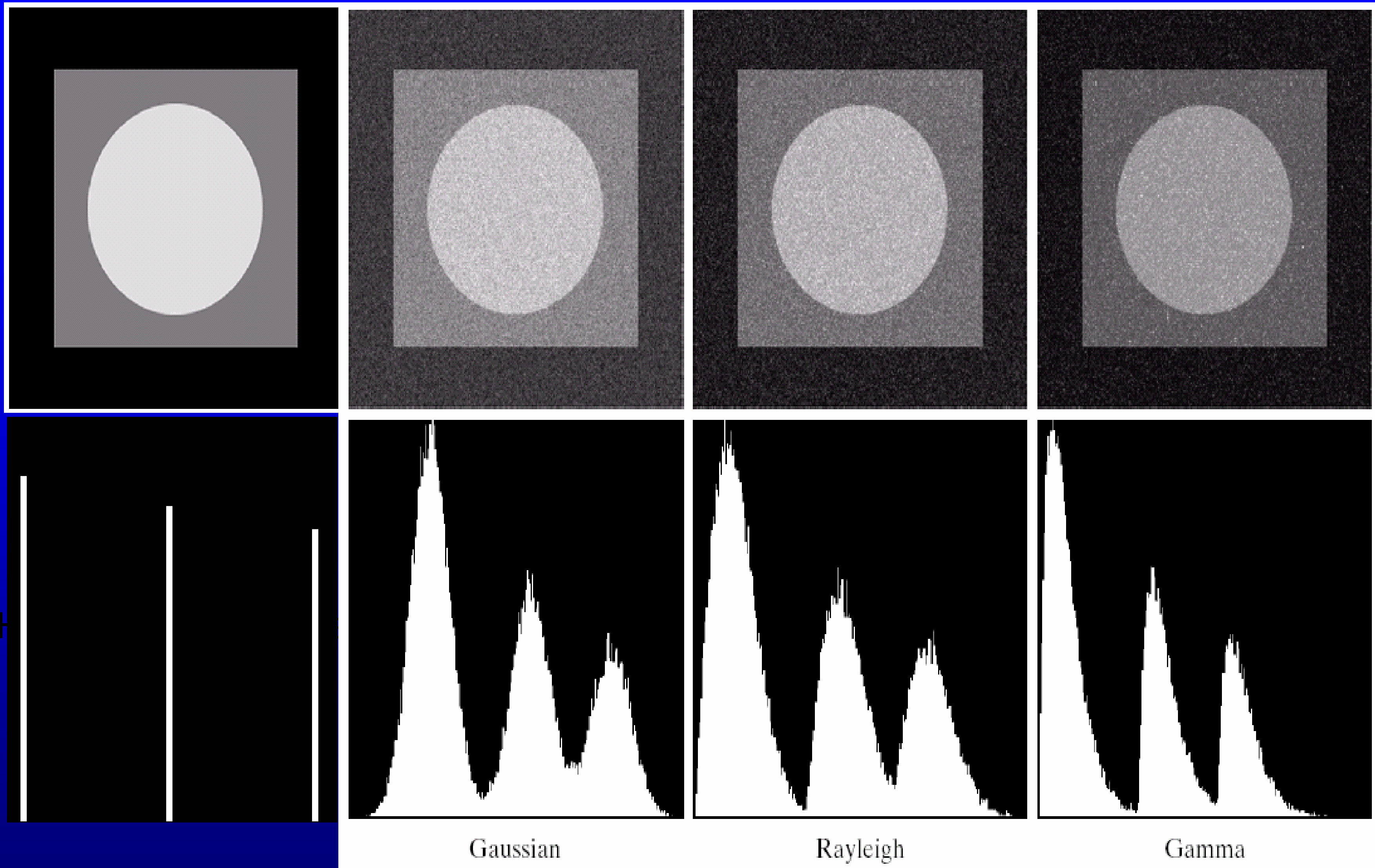

(a)
(b)
(c)
(d)


3.3
35V
1206


histograma(u)
645
322
0
128
255
u


EL AMOR
DE CHILE
o
histoy
y

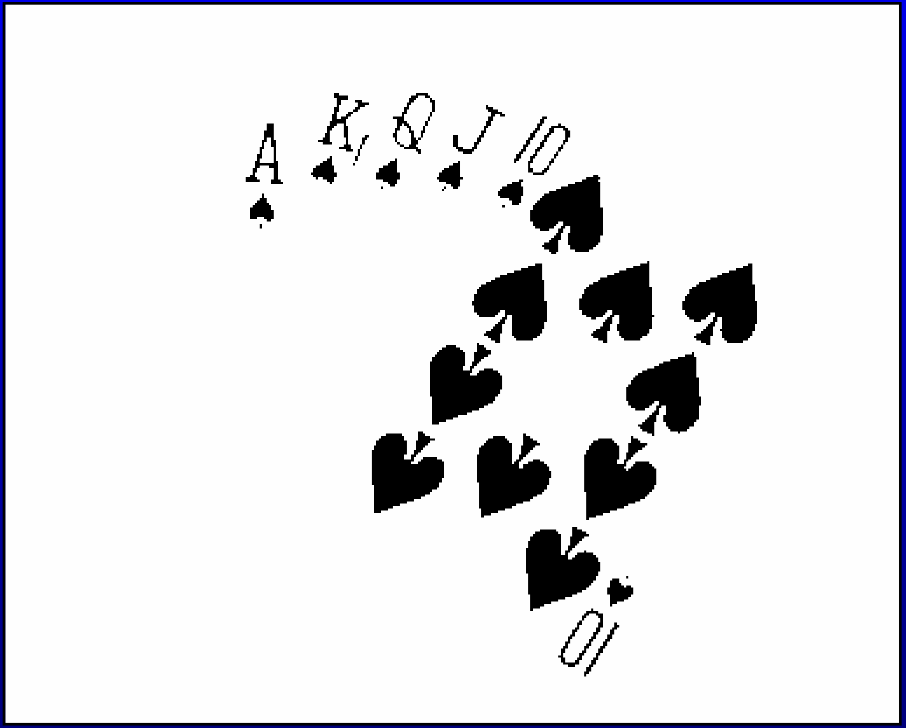

EL AMOR
histox
0
x

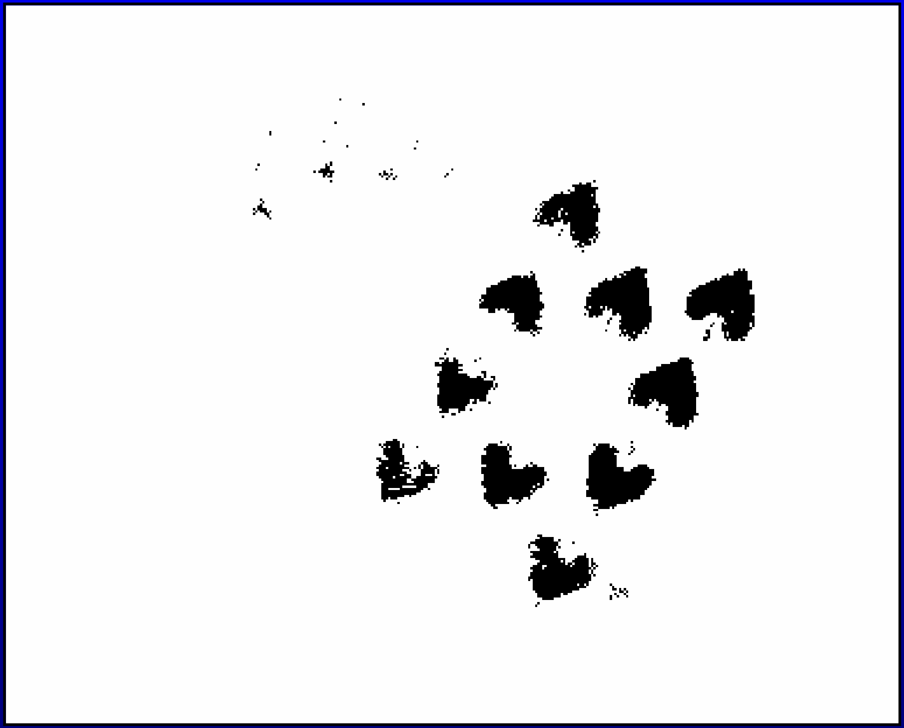

Gaussian
Rayleigh
Gamma

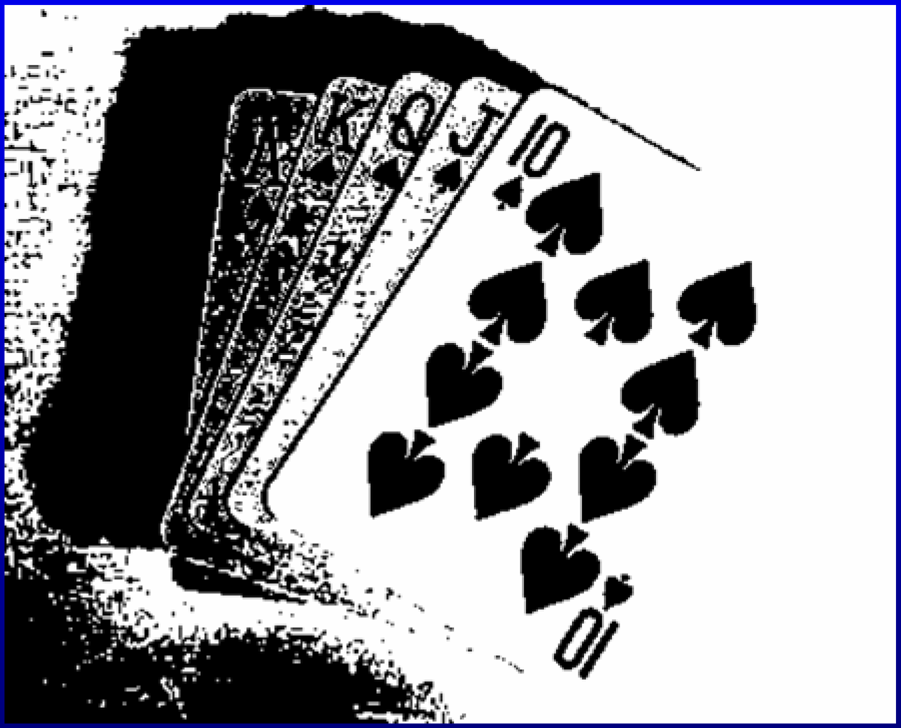
Uso de Umbrales

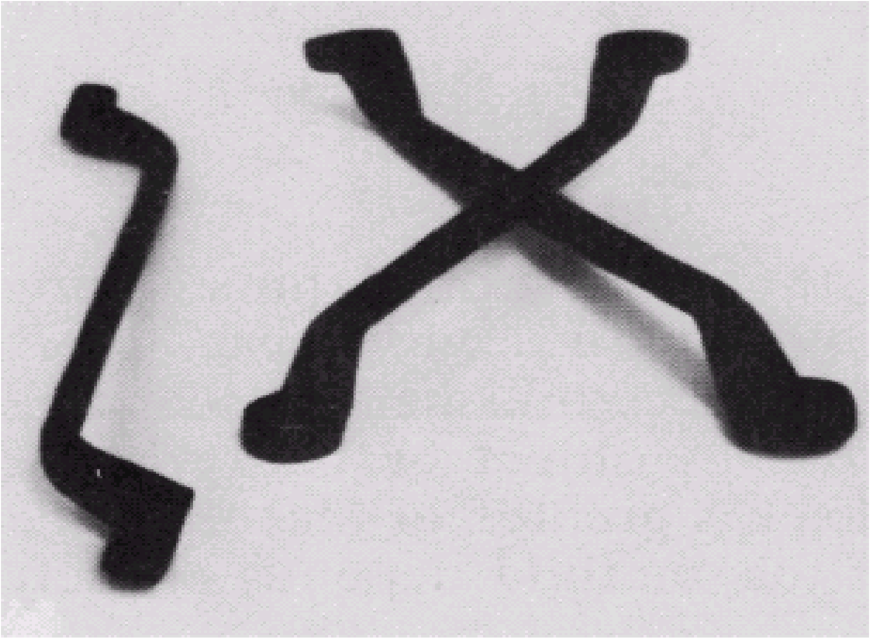
$$g(x, y) = \begin{cases} 1\, if \;\; f(x, y) > T \\ 0\, if \;\; f(x, y) \leq T \end{cases}$$

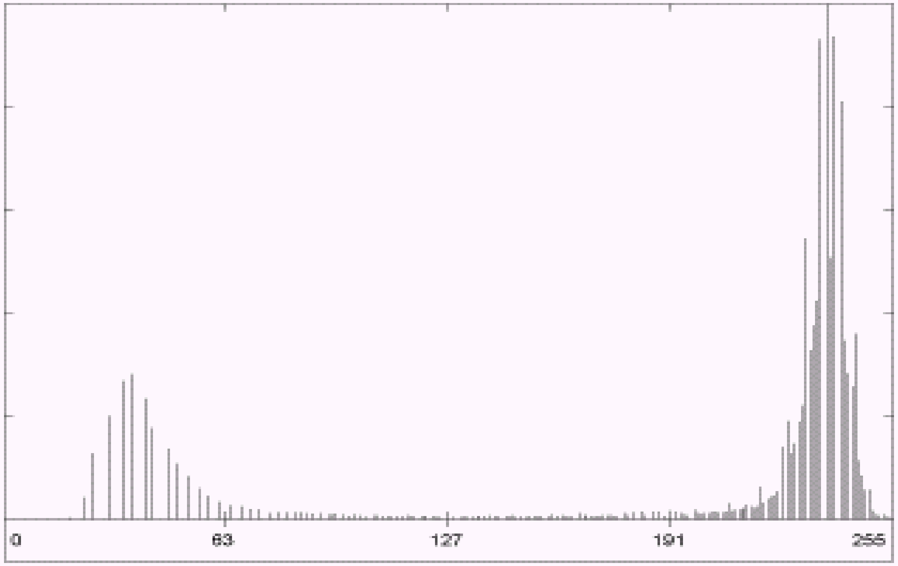

A
K
Q
J
10
10

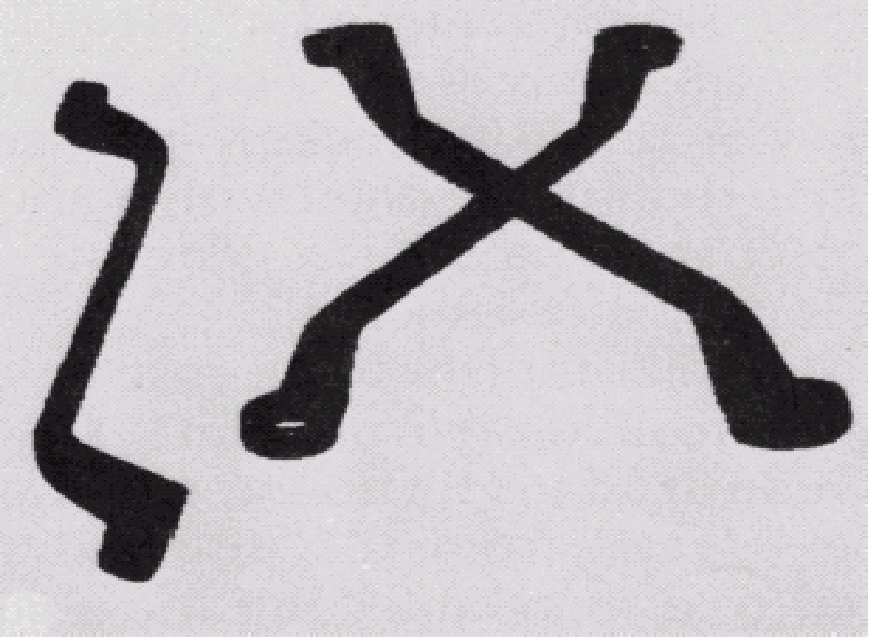

A
K
Q
J
10
10

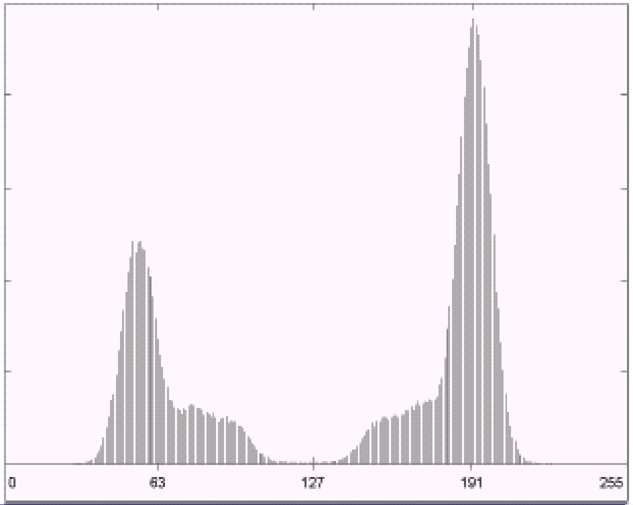


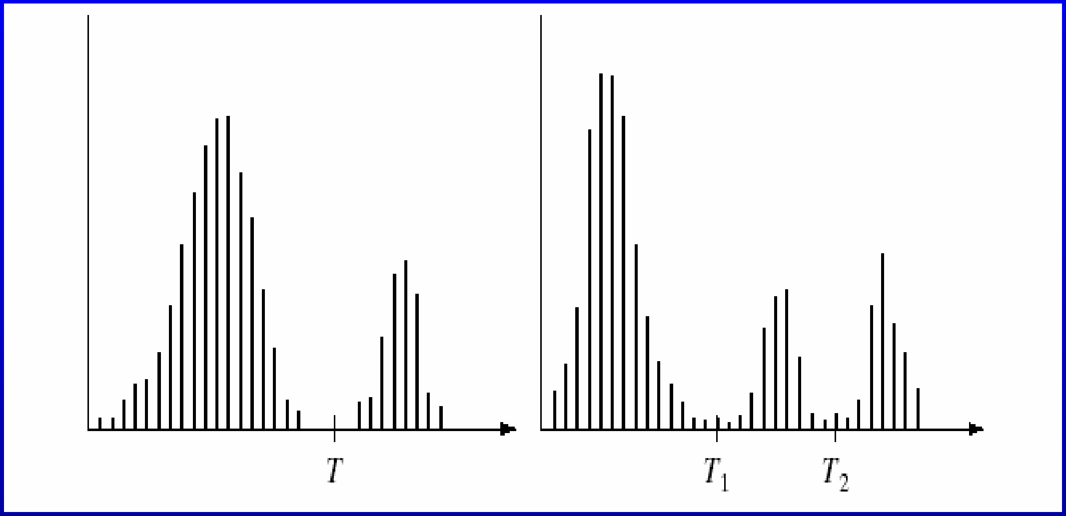




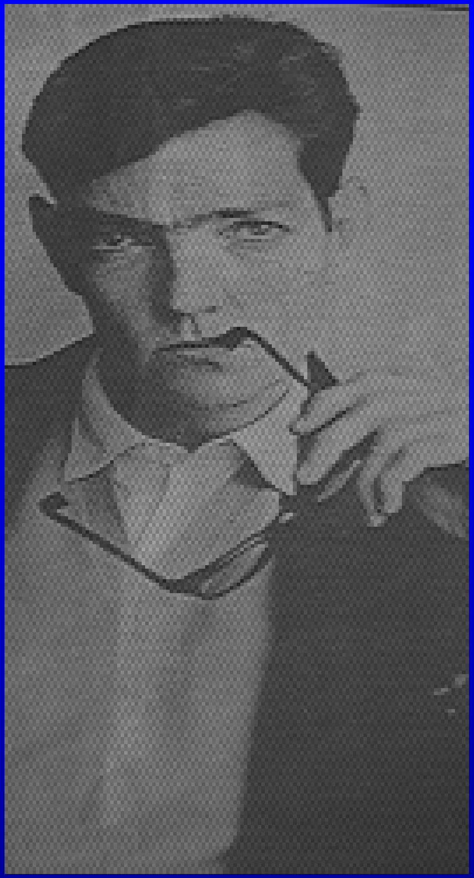

0
63
127
191
255

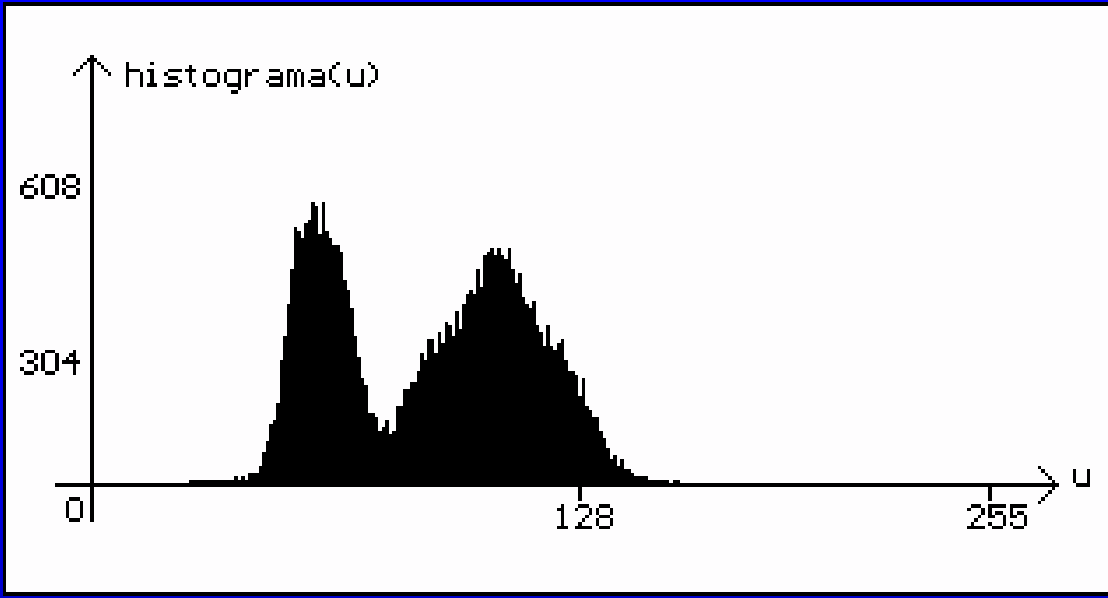



0
63
127
191
255

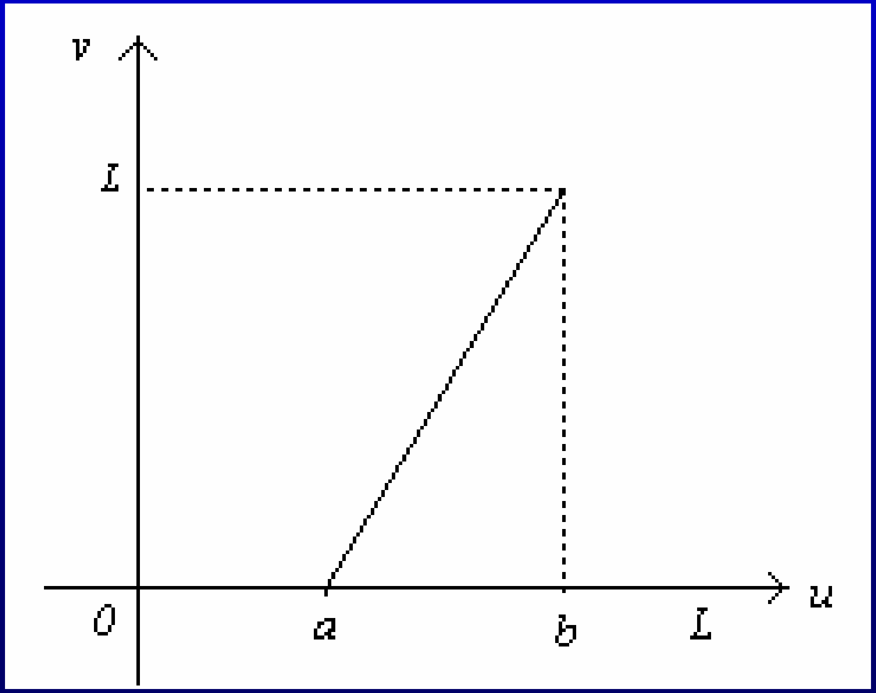



Varios umbrales

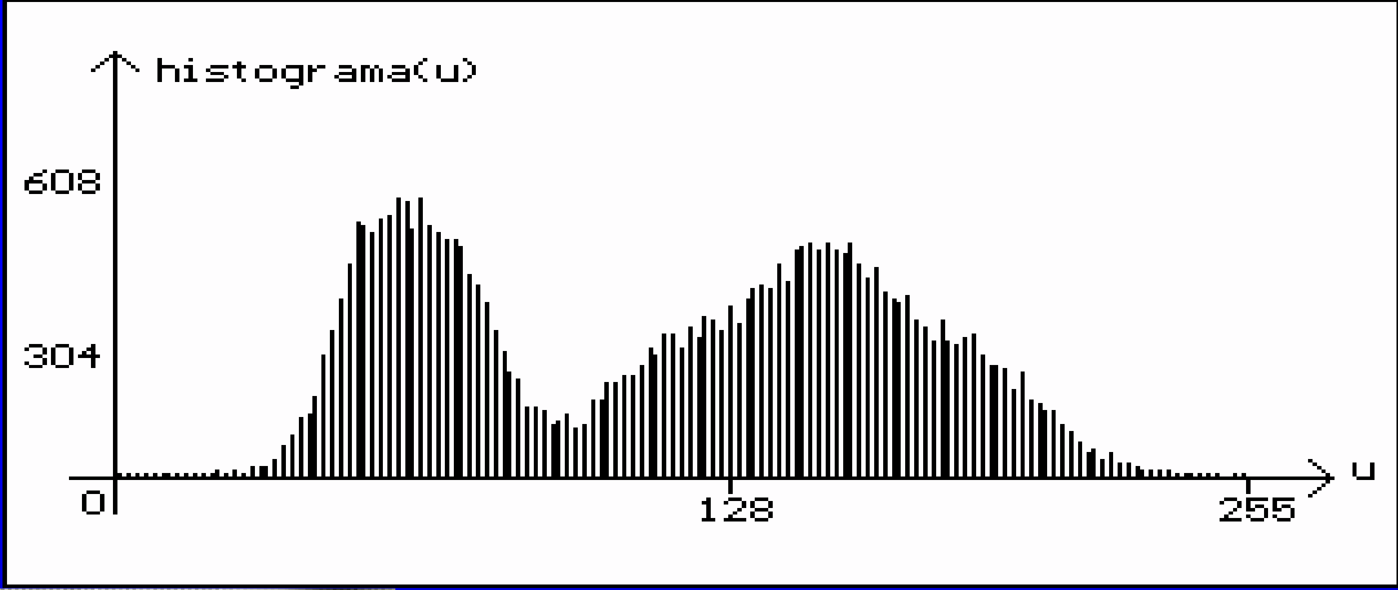


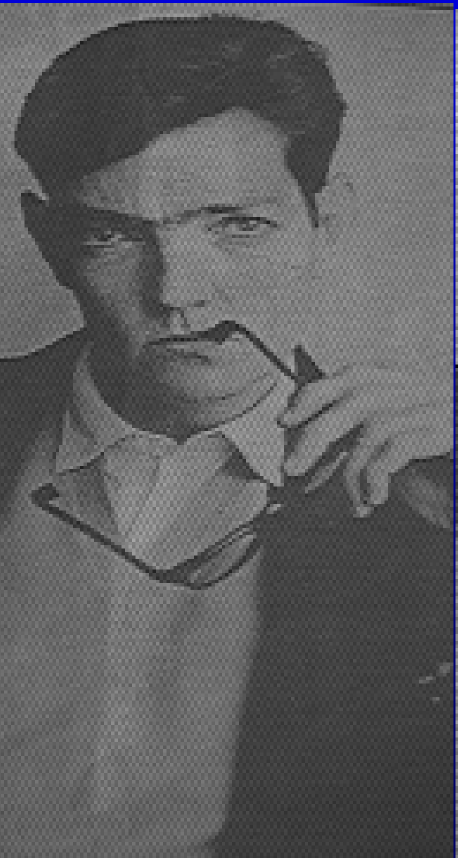


histograma(u)
608
304
0
128
255
u

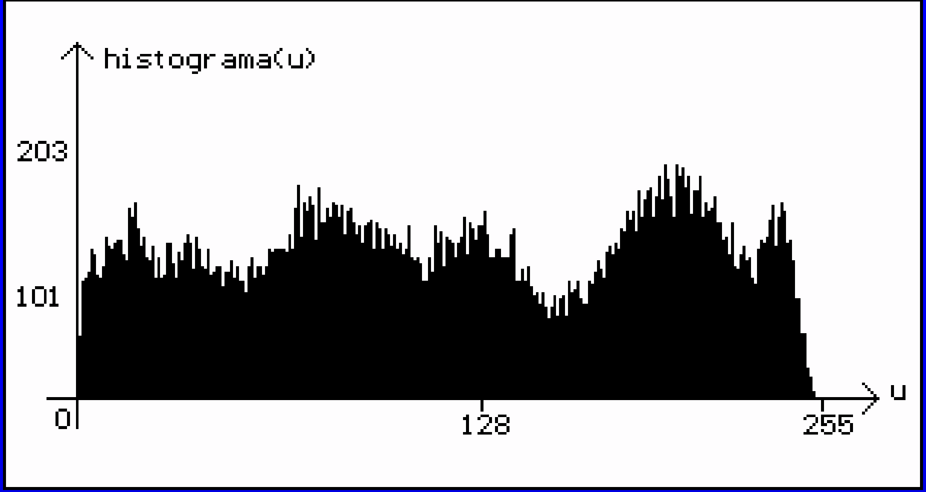


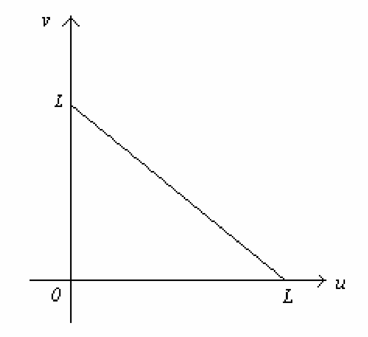
v
L
0
a
b
L
u


histograma(u)
608
304
0
128
255
u

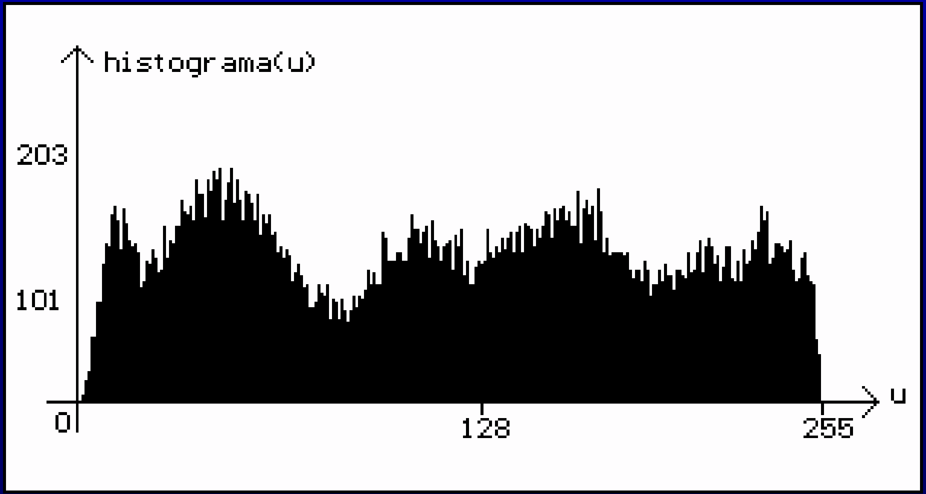



Perfectly Yo

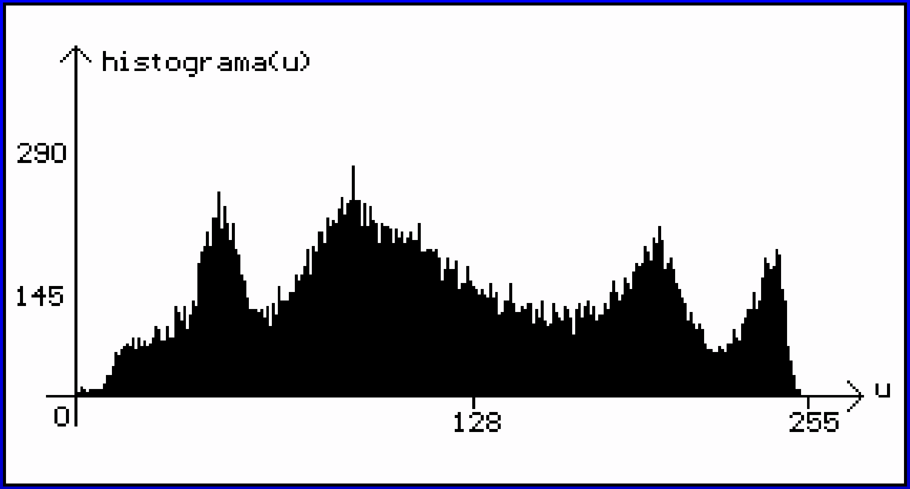

histograma(u)
203
101
0
128
255
u

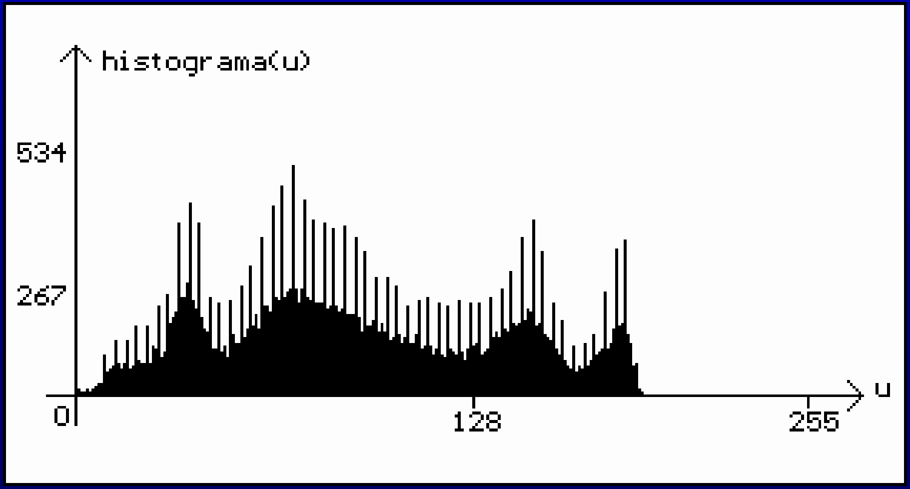

v
L
0
L
u


Perfectly Yo

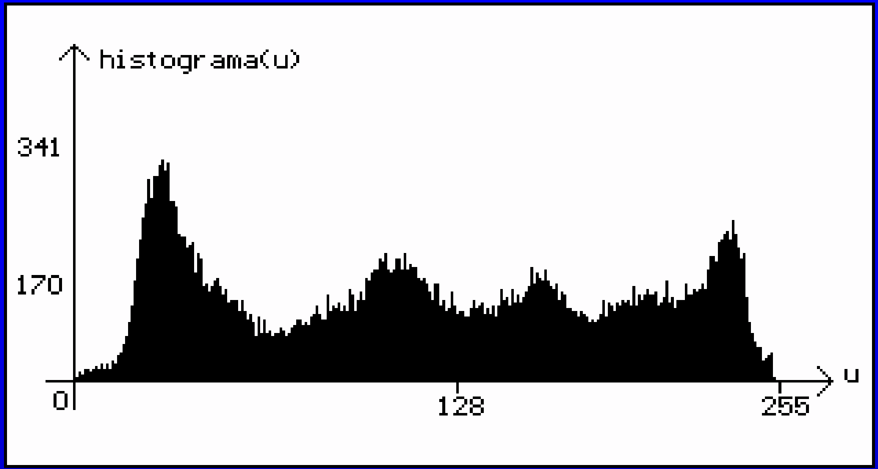

histograma(u)
203
101
0
128
255
u

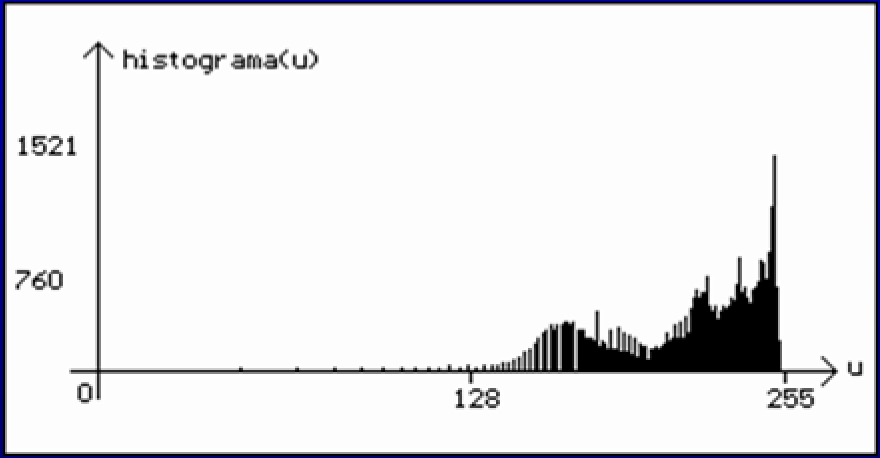
Compresión lineal de rango





Compresión logarítmica de rango





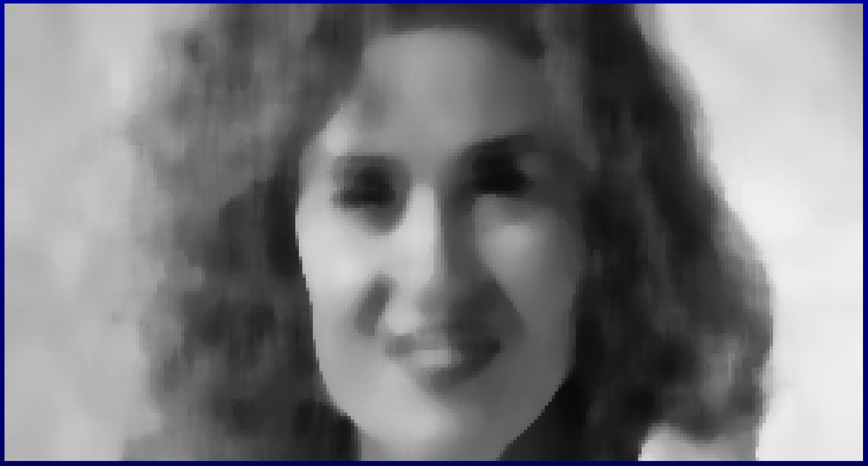
- Procesamiento de múltiples imágenes
    - operaciones lógicas
    - matemáticas +-*/ (razón espectral i.r.)
    - reducción de ruido

- Composición de Imágenes
    - imágenes no relacionadas

Substracción de Imágenes

- Detección de fallas – lineas de producción
- Monitoreo de seguridad
- Substracción de fondo – vasos sanguíneos
- Detección de movimientos
- Registro de imágenes

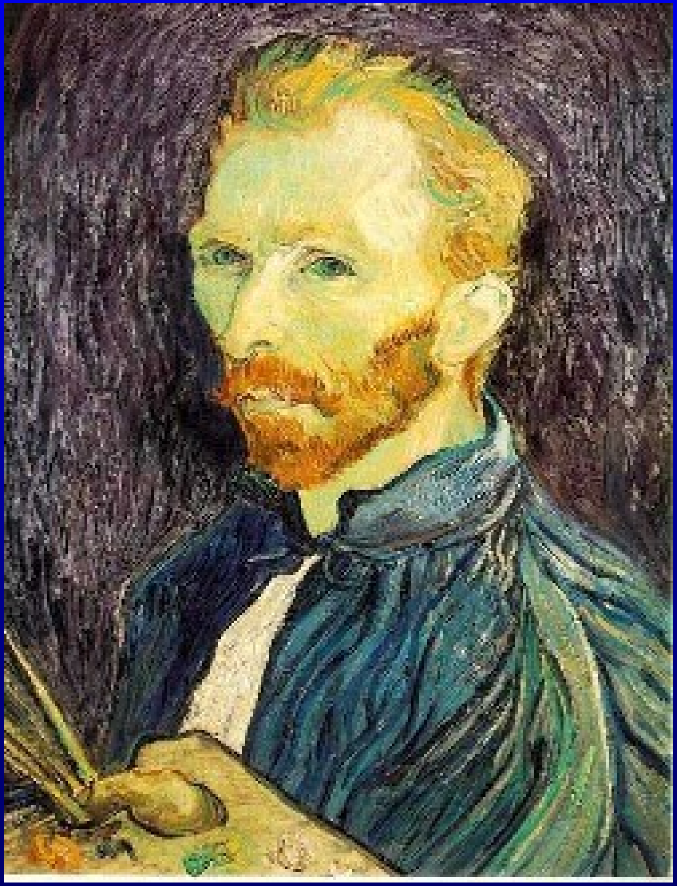
- Procesamiento de múltiples imágenes
    - operaciones lógicas
    - matemáticas +-*/
    - reducción de ruido



Magnificación por replicación

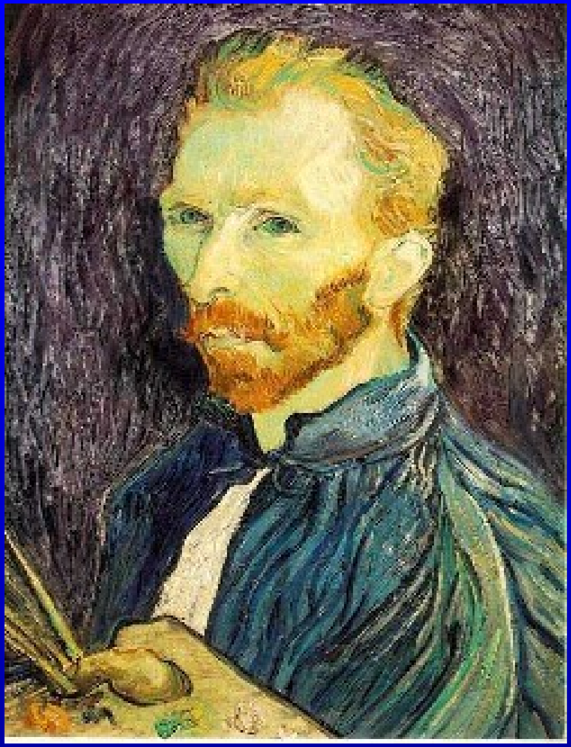
Magnificación por interpolación lineal

Submuestreo



1/4

1/8



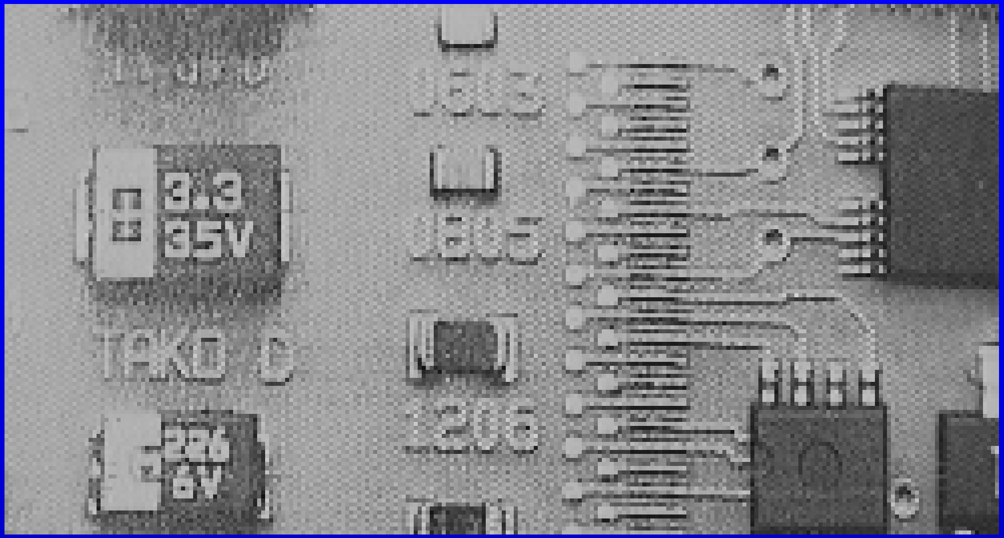
1/2

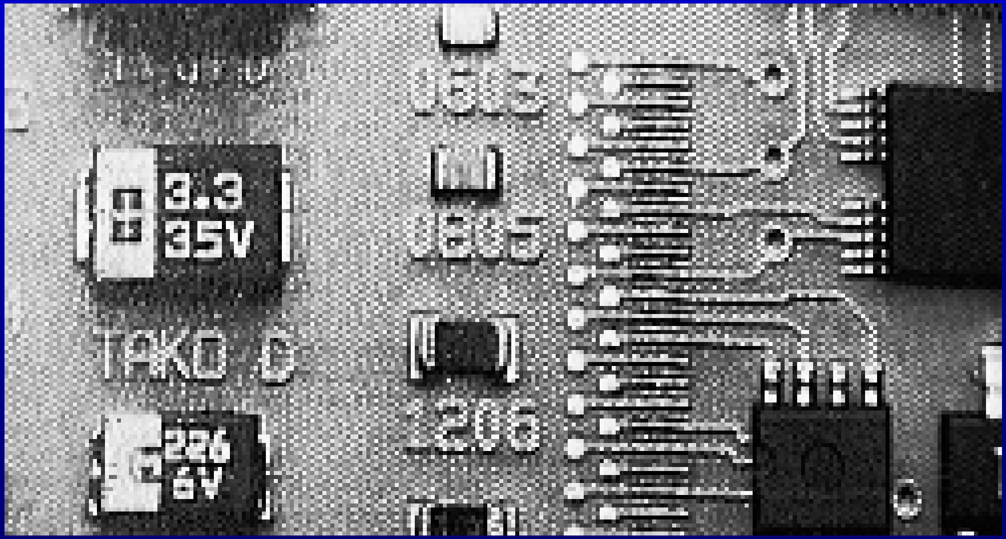
1/4 (2x zoom)

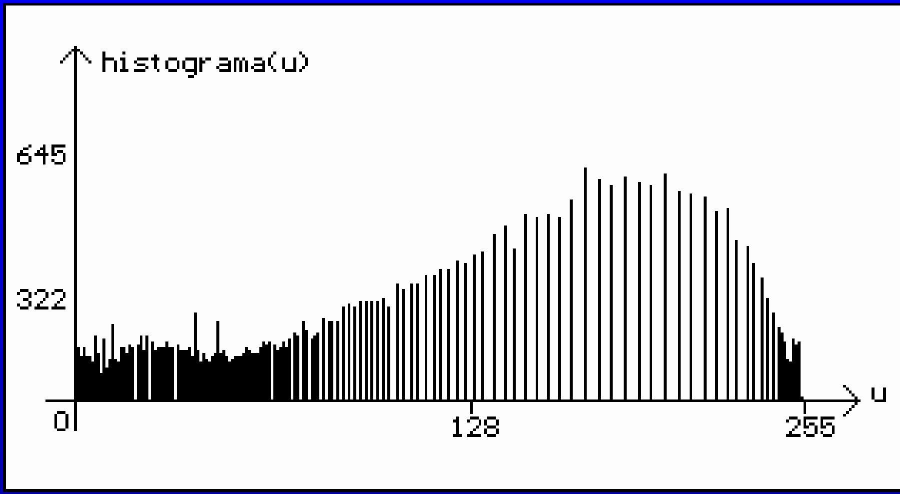
1/8 (4x zoom)

Medios-tonos

Ecualización de histogramas

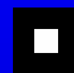


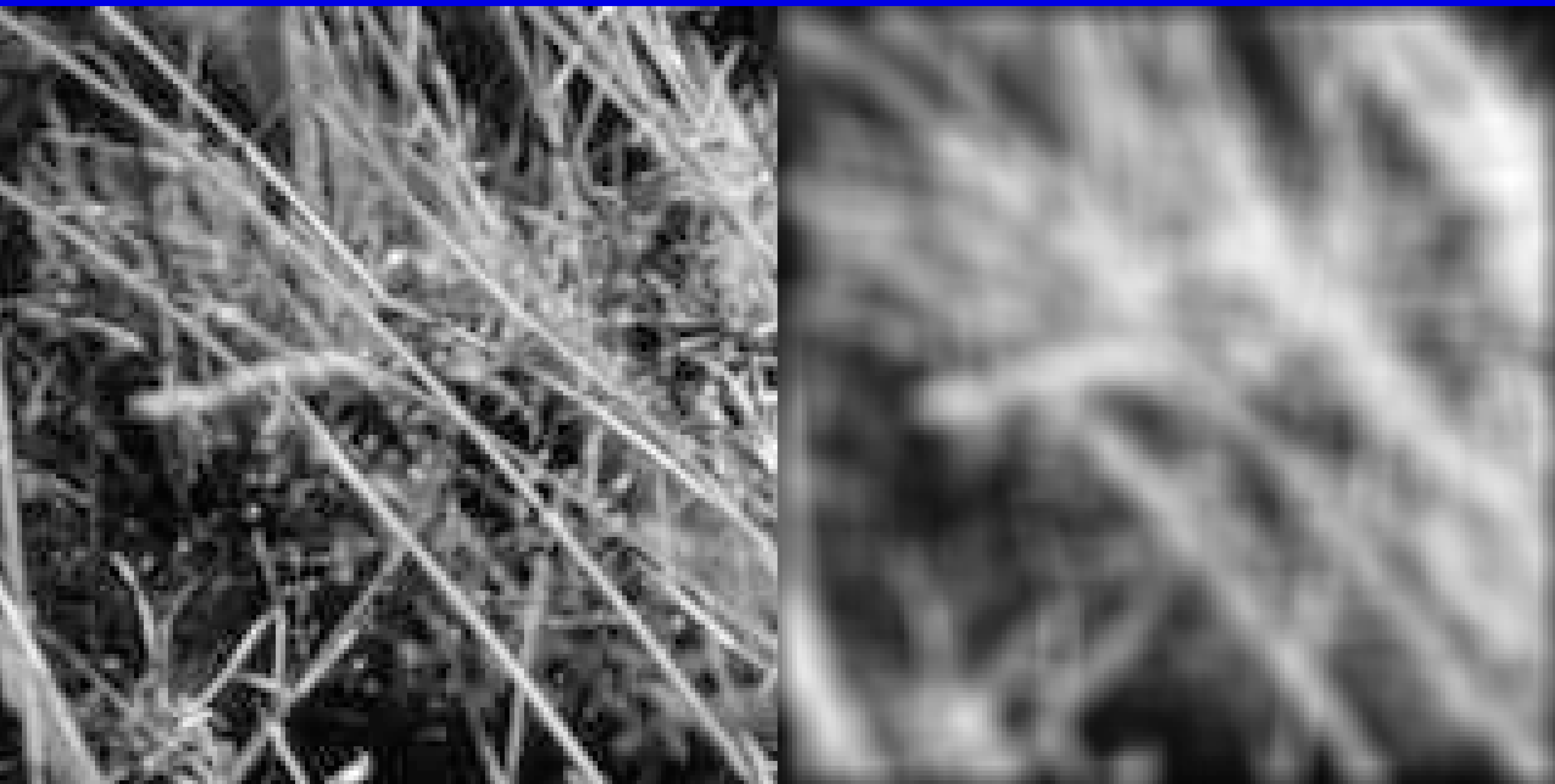




Operaciones Espaciales: Promediación

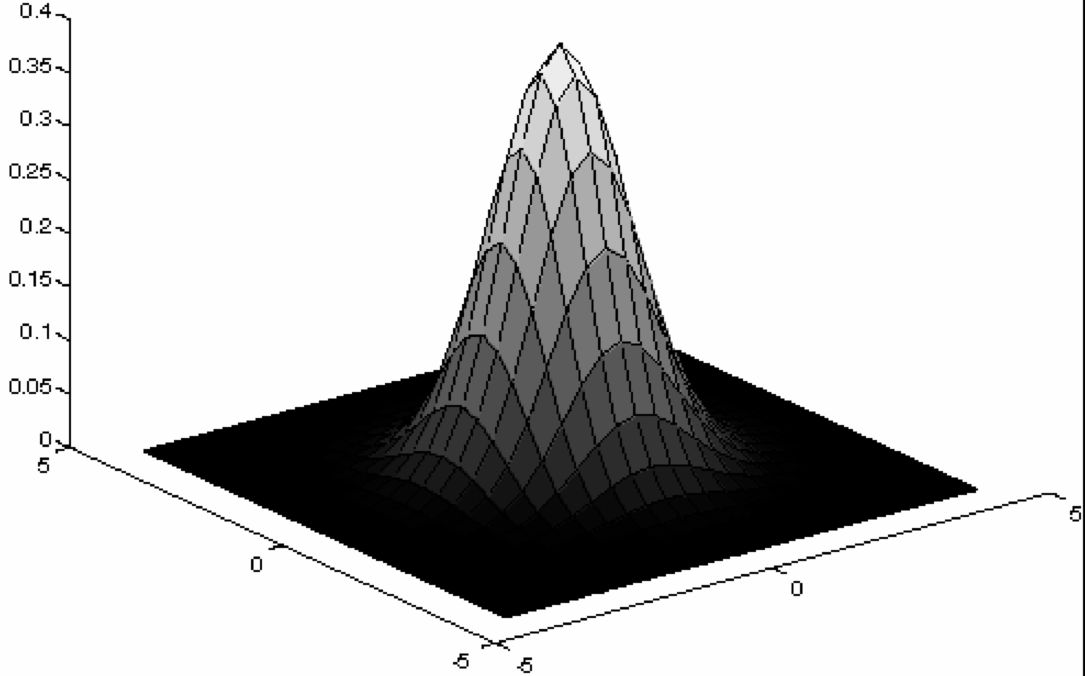
Suavizado por promediación

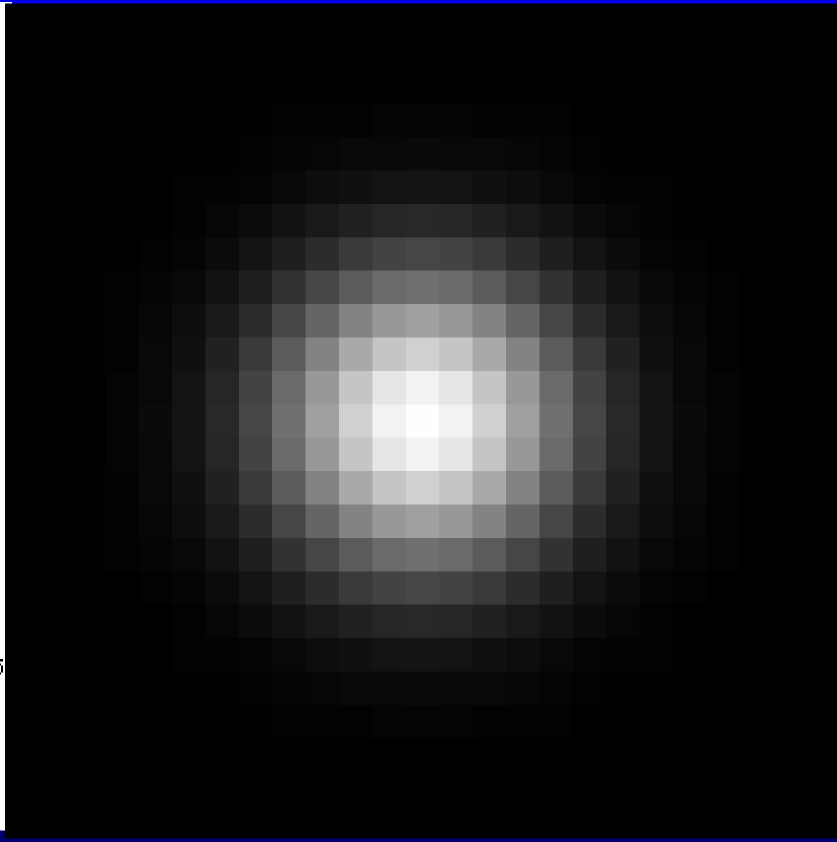




Suavizado con Gaussiana

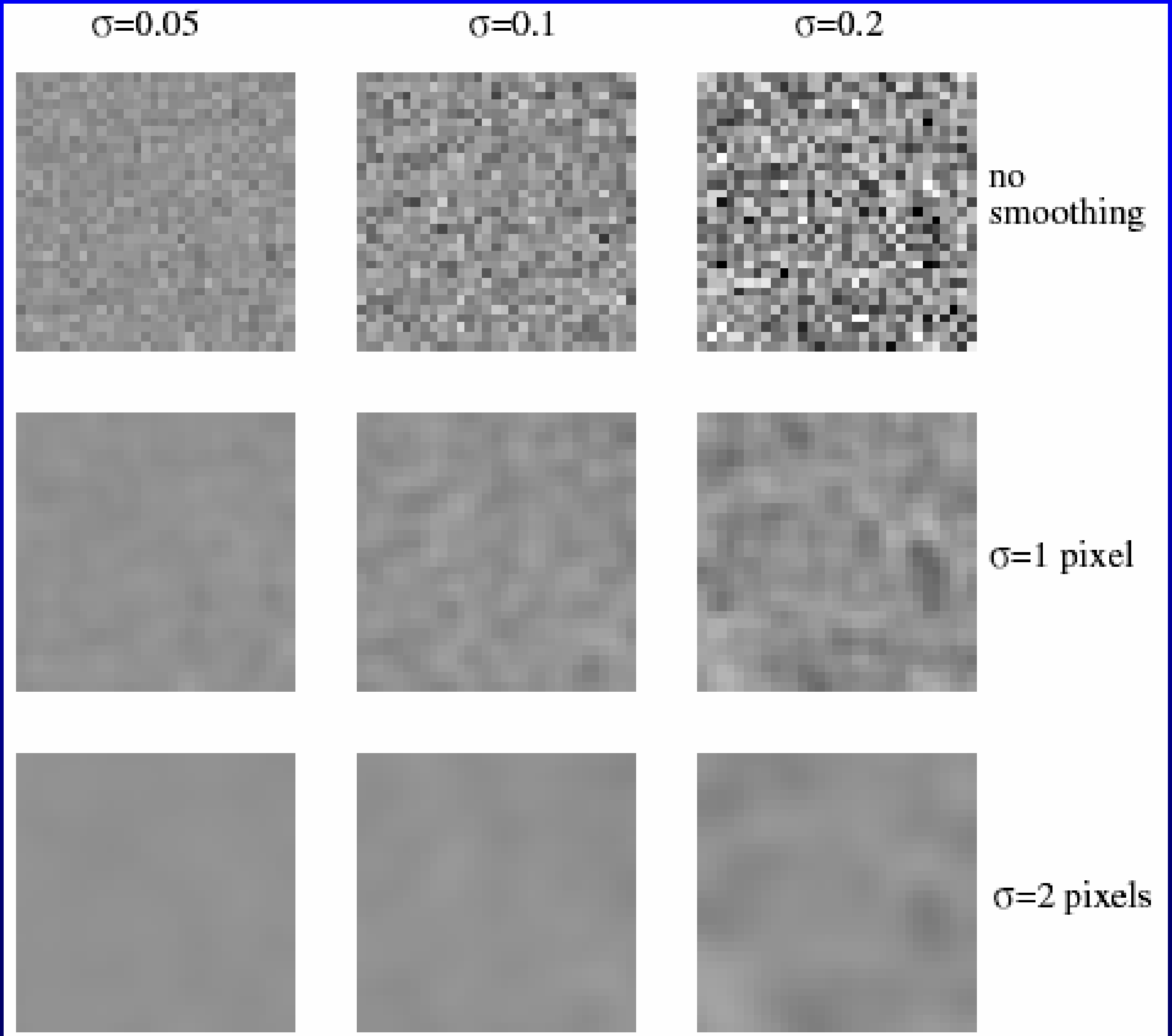
$$\exp\left(-\left(\frac{x^2+y^2}{2\sigma^2}\right)\right)$$

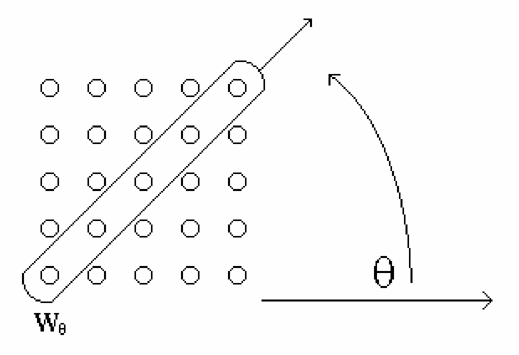




Filtrado Gaussiano

Ruido Gaussiano (columnas) suavizado por un filtro Gaussiano (filas)





Promediación Direccional

Filtrado Mediano

- Eliminación de artefactos
- Ruido binario




Filtrado

Temporal

Diferencias

$$\frac{\partial f}{\partial x} = \lim_{\varepsilon \to 0}\left(\frac{f(x+\varepsilon, y)}{\varepsilon} - \frac{f(x,y)}{\varepsilon} \right)$$

$$\frac{\partial f}{\partial x} \approx \frac{f(x_{n+1}, y) - f(x_n, y)}{\Delta x}$$

$$\frac{\partial f}{\partial x} = f(x+1) - f(x)$$

Derivada Hacia Adelante

Diferencia Central

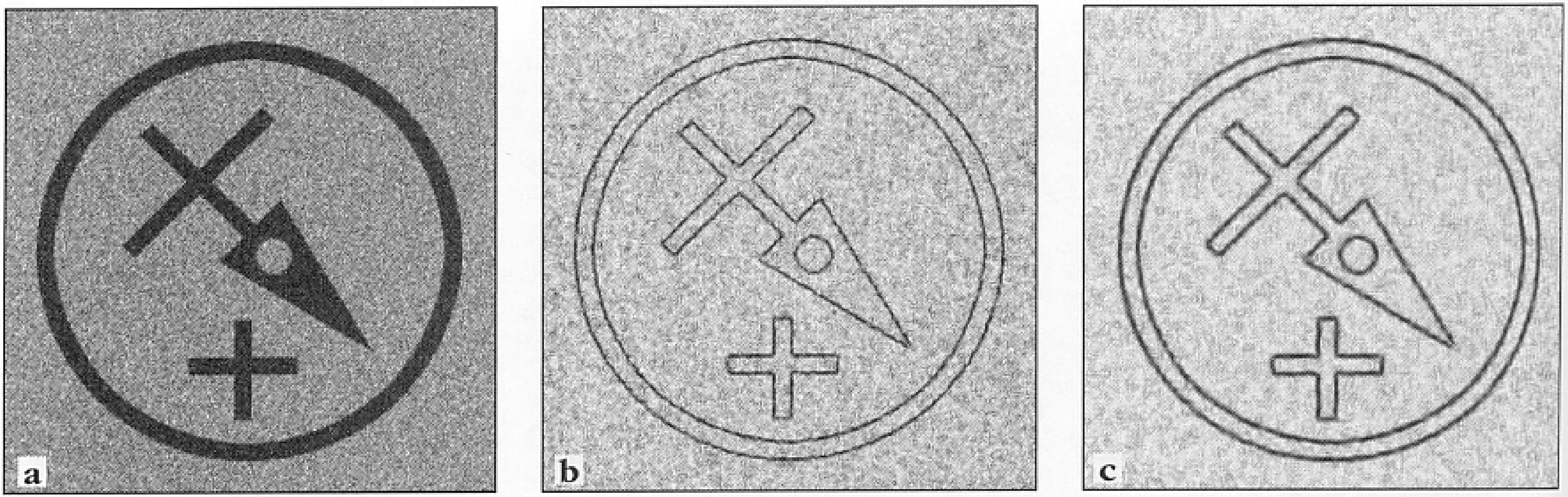
Operador de Prewitt

Operador de Sobel

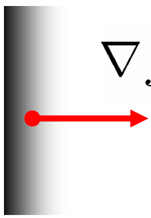
Operador Isotrópico

Operador Roberts

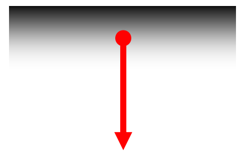
Sobel 3x3 y 5x5



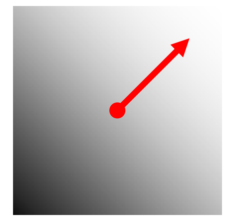
$$\nabla f = \left[\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y}\right]$$



$$\nabla f = \left[\frac{\partial f}{\partial x}, 0\right]$$



$$\nabla f = \left[0, \frac{\partial f}{\partial y}\right]$$



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

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

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

Horizontal Gradients Kernels v_x: $g_x = u * v_x$

Roberts

0	1
-1	0

Prewitt

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

Sobel

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

Isotropic

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

Vertical Gradients Kernels v_y: $g_y = u * v_y$

Roberts

1	0
0	-1

Prewitt

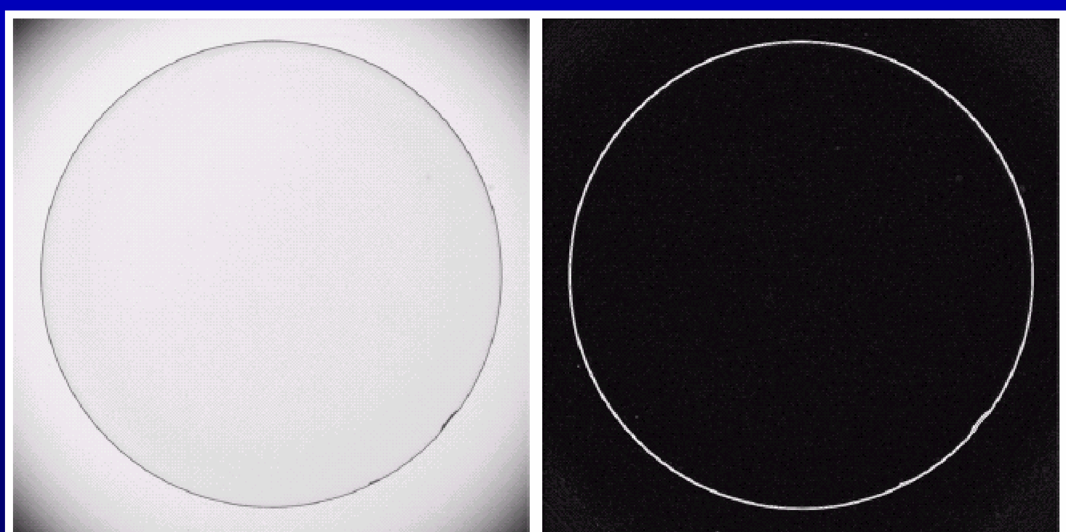
-1	-1	-1
0	0	0
1	1	1

Sobel

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

Isotropic

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



Sobel

Gradient Operators (threshold)

$$g(i,j) = \sqrt{g_x^2(i,j) + g_y^2(i,j)} \quad \text{or} \quad g(i,j) = |g_x(i,j)| + |g_y(i,j)|$$

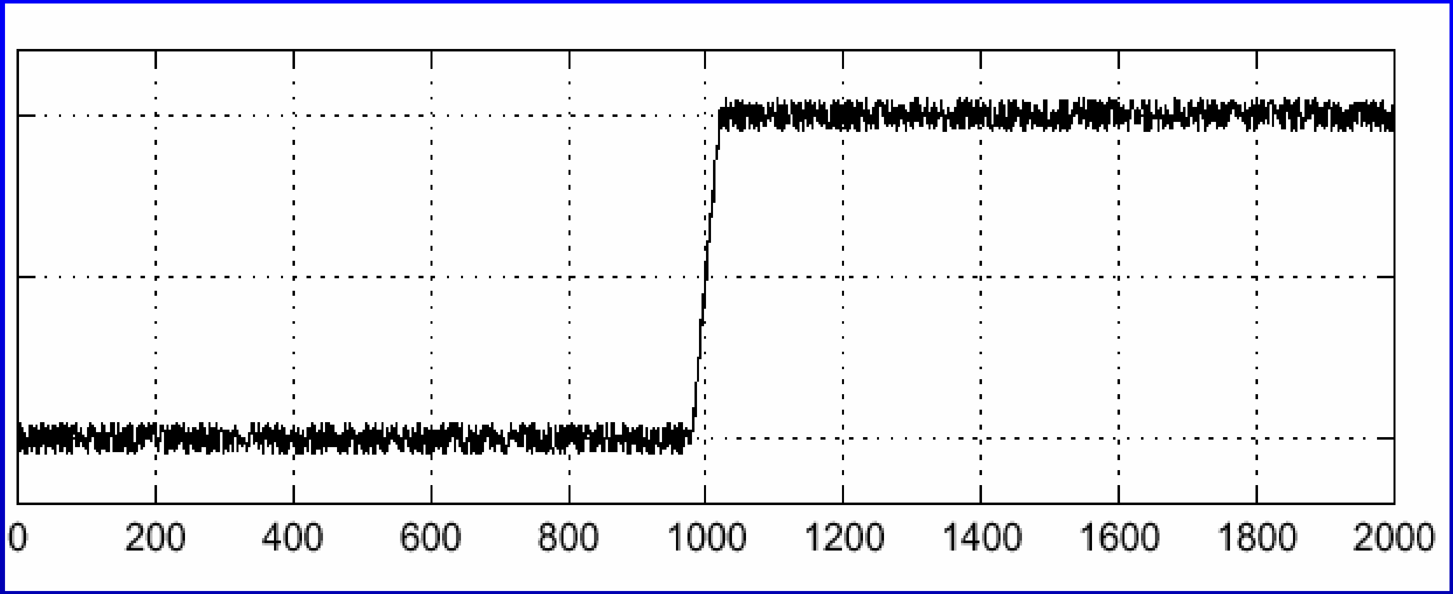
$$\theta_g(i,j) = \tan^{-1} \frac{g_y(i,j)}{g_x(i,j)}$$

$$\nabla f = mag(\nabla \mathrm{f})$$
$$= \left[G_x^2 + G_y^2\right]^{1/2}$$
$$= \left[\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2\right]^{1/2}$$

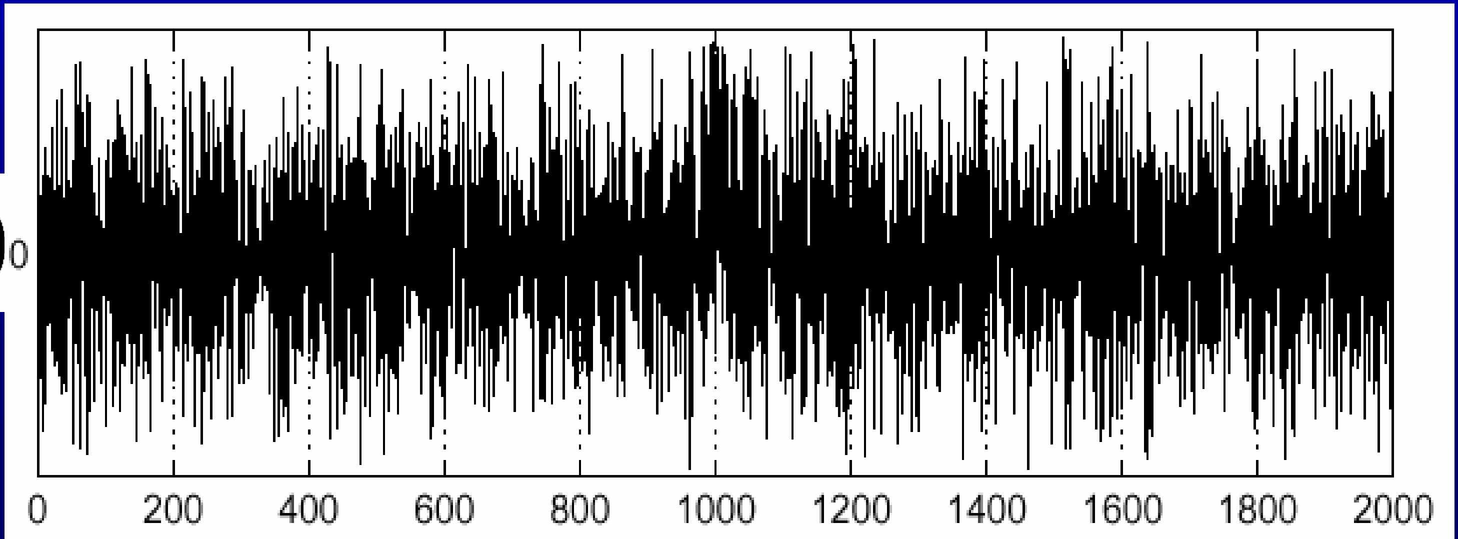
$$\nabla f \approx |G_x| + |G_y|$$

Efecto del ruido en la detección de bordes

$$f(x)$$



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



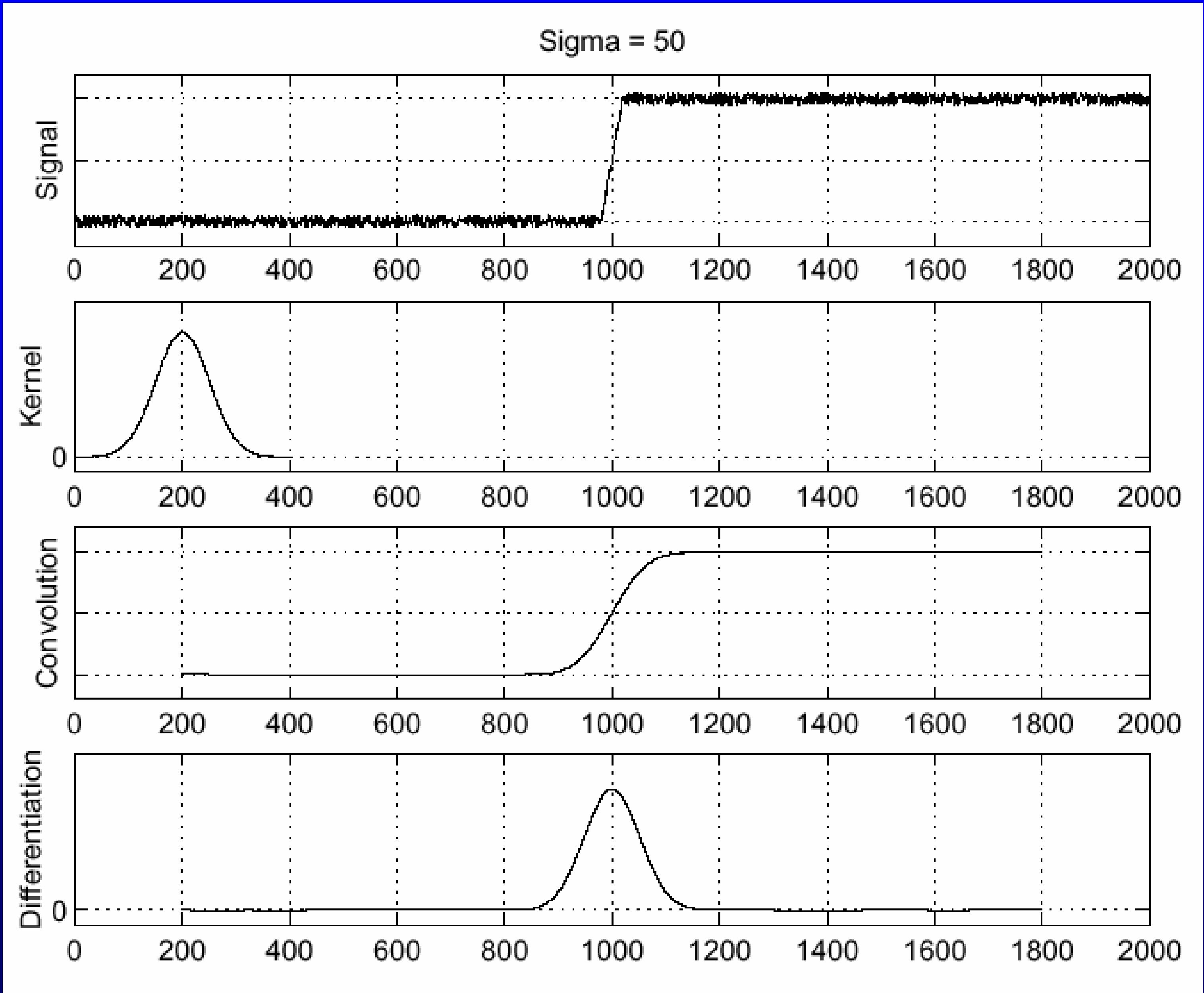
Solución: suavizar y luego buscar máximo en $\frac{\partial}{\partial x}(h \star f)$

f

h

$h \star f$

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



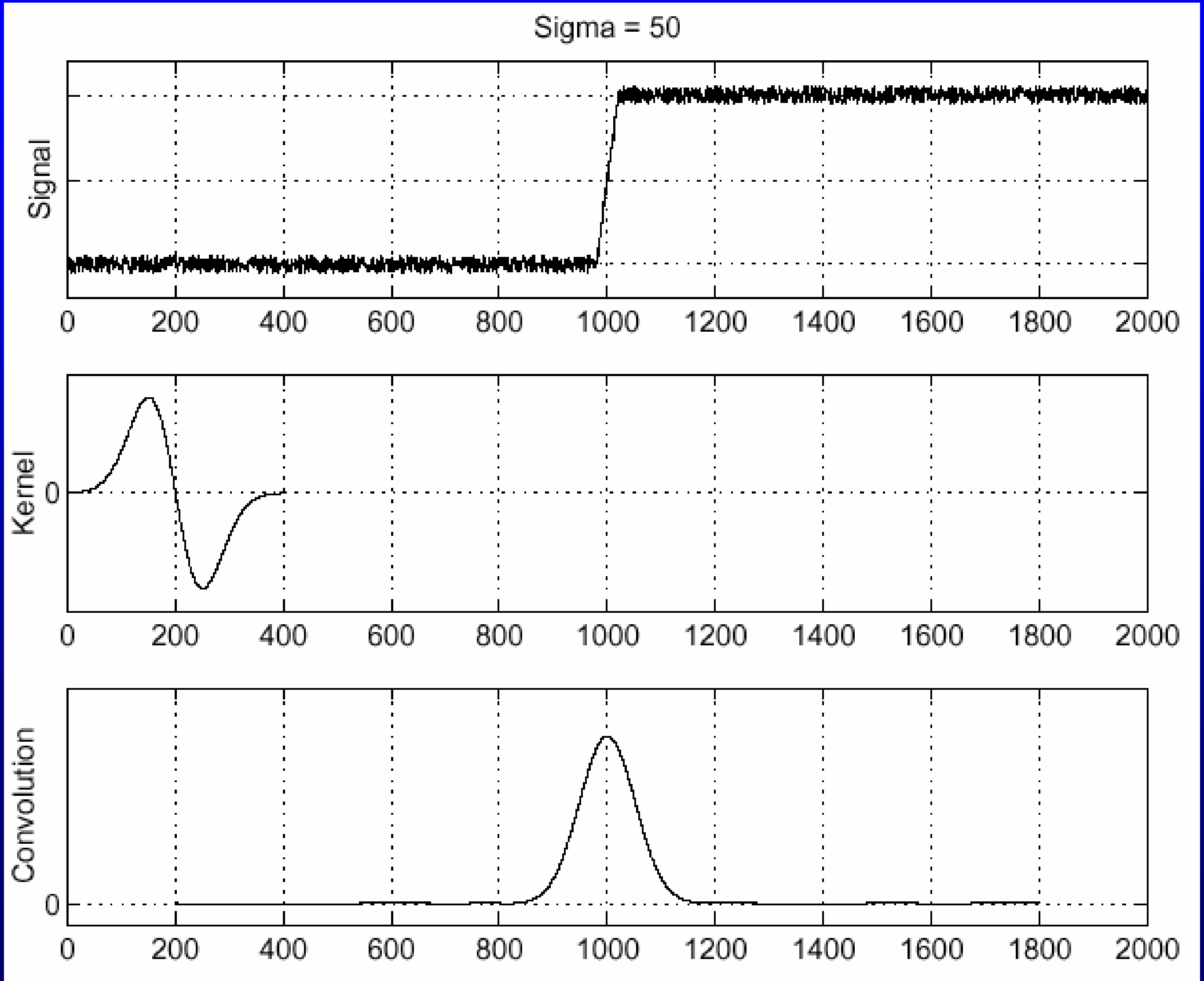
Teorema de la derivada de la convolución:

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

f

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

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



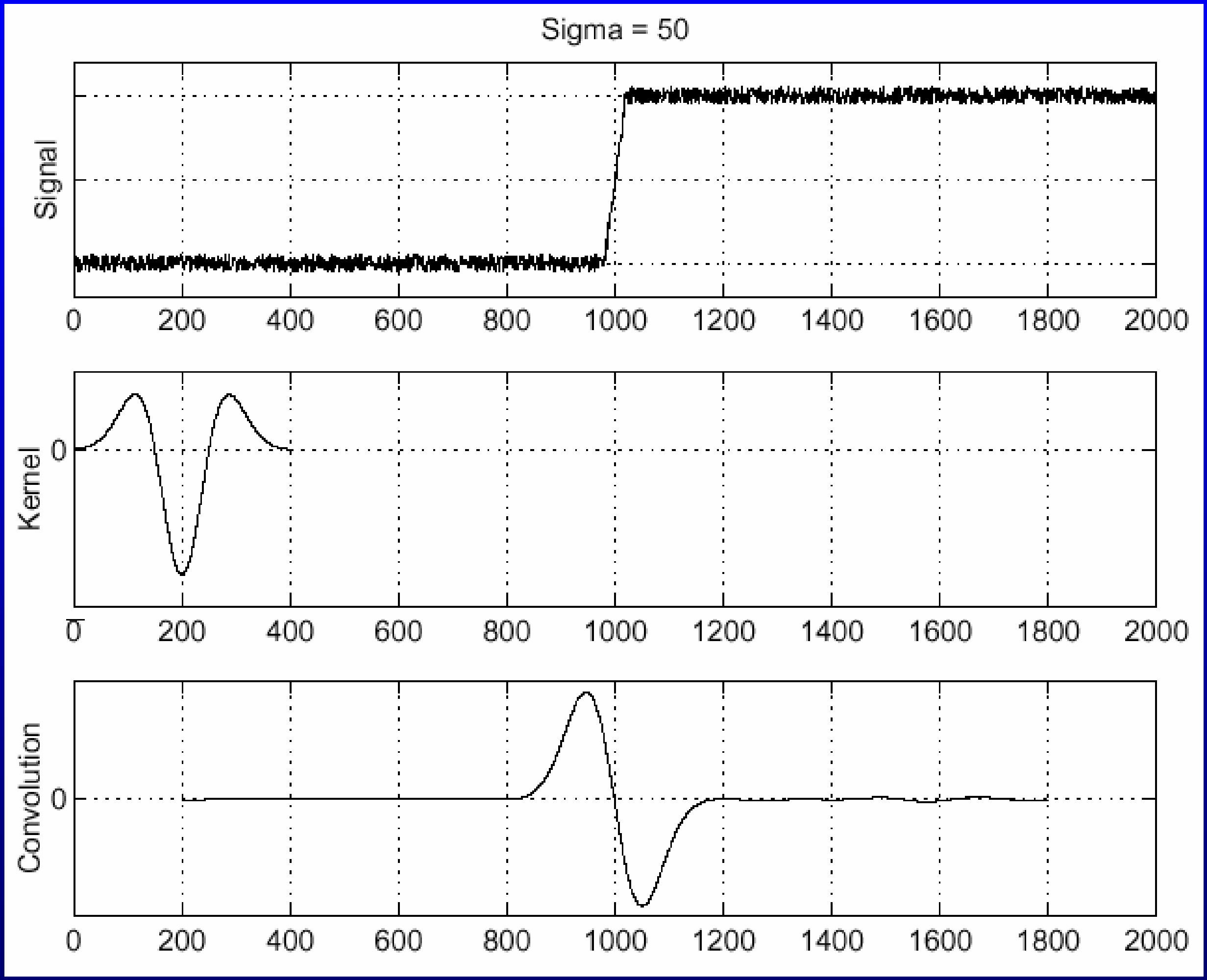
Operador LoG

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

f

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

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



$$\nabla^2 f = \frac{\partial^2 f}{\partial^2 x} + \frac{\partial^2 f}{\partial^2 y}$$

$$\frac{\partial^2 f}{\partial^2 x} = f(x+1, y) + f(x-1, y) - 2f(x, y)$$

$$\frac{\partial^2 f}{\partial^2 y} = f(x, y+1) + f(x, y-1) - 2f(x, y)$$

$$\nabla^2 f = [f(x+1, y) + f(x-1, y) + f(x, y+1) + f(x, y-1)] - 4f(x, y)$$

0	1	0
1	-4	1
0	1	0

Laplace Operators (zero crossing)

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$$

0	−1	0
−1	4	−1
0	−1	0

−1	−1	−1
−1	8	−1
−1	−1	−1

1	−2	1
−2	4	−2
1	−2	1

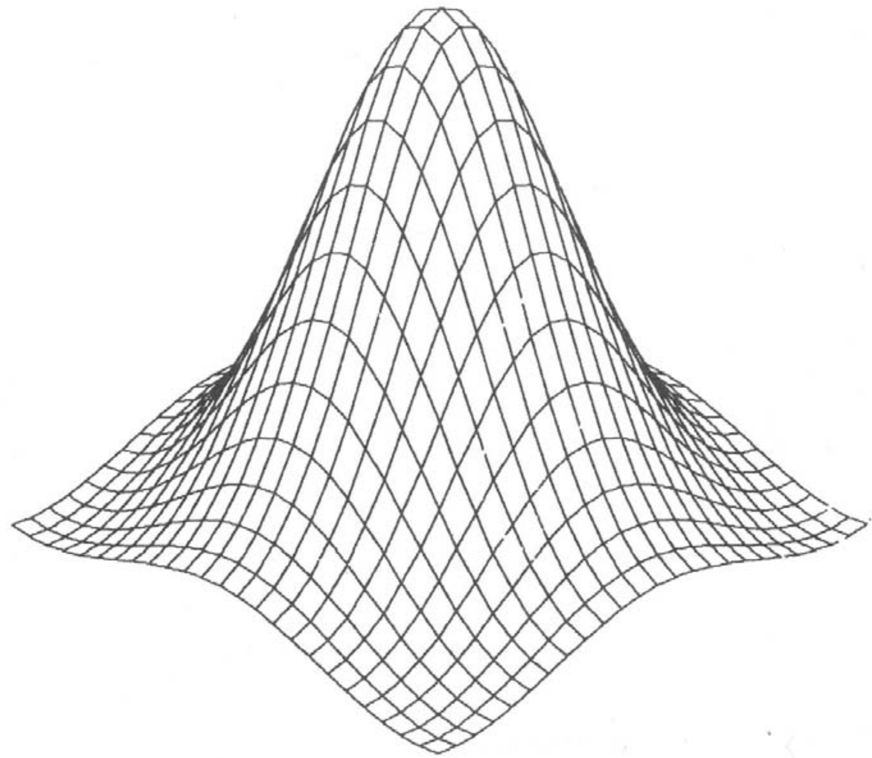
Filtro Gaussiano

7×7 Gaussian mask

1	1	2	2	2	1	1
1	2	2	4	2	2	1
2	2	4	8	4	2	2
2	4	8	16	8	4	2
2	2	4	8	4	2	2
1	2	2	4	2	2	1
1	1	2	2	2	1	1

15×15 Gaussian mask

2	2	3	4	5	5	6	6	6	5	5	4	3	2	2
2	3	4	5	7	7	8	8	8	7	7	5	4	3	2
3	4	6	7	9	10	10	11	10	10	9	7	6	4	3
4	5	7	9	10	12	13	13	13	12	10	9	7	5	4
5	7	9	11	13	14	15	16	15	14	13	11	9	7	5
5	7	10	12	14	16	17	18	17	16	14	12	10	7	5
6	8	10	13	15	17	19	19	19	17	15	13	10	8	6
6	8	11	13	16	18	19	20	19	18	16	13	11	8	6
6	8	10	13	15	17	19	19	19	17	15	13	10	8	6
5	7	10	12	14	16	17	18	17	16	14	12	10	7	5
5	7	9	11	13	14	15	16	15	14	13	11	9	7	5
4	5	7	9	10	12	13	13	13	12	10	9	7	5	4
3	4	6	7	9	10	10	11	10	10	9	7	6	4	3
2	3	4	5	7	7	8	8	8	7	7	5	4	3	2
2	2	3	4	5	5	6	6	6	5	5	4	3	2	2



(a)

LoG

5×5 Laplacian kernel

0	0	-1	0	0
0	-1	-2	-1	0
-1	-2	16	-2	-1
0	-1	-2	-1	0
0	0	-1	0	0

7×7 Mexican hat kernel

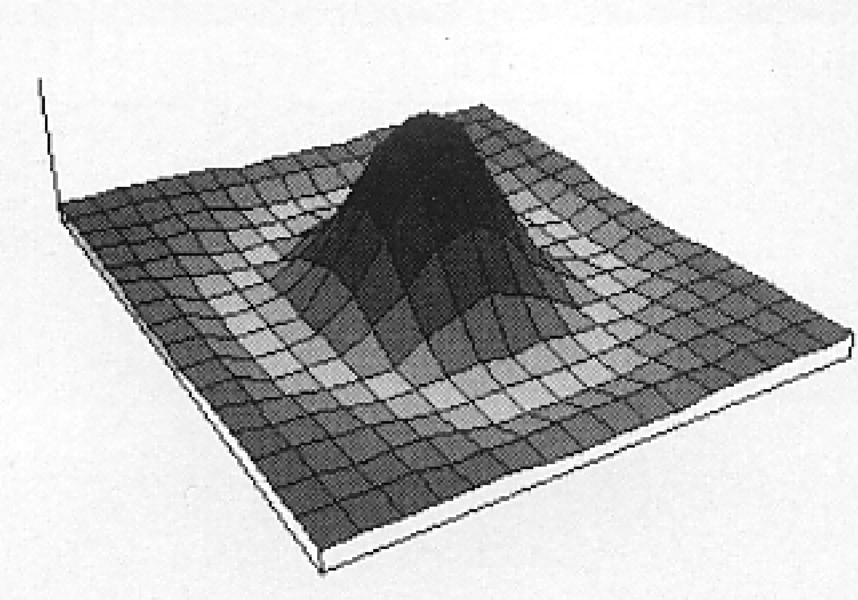
0	0	-1	-1	-1	0	0
0	-1	-3	-3	-3	-1	0
-1	-3	0	7	0	-3	-1
-1	-3	7	24	7	-3	-1
-1	-3	0	7	0	-3	-1
0	-1	-3	-3	-3	-1	0
0	0	-1	-1	-1	0	0

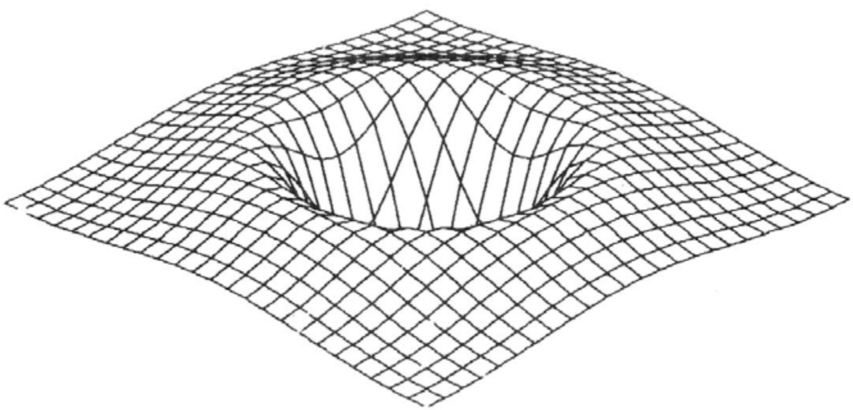
13×13 Mexican hat kernel

0	0	0	0	0	-1	-1	-1	0	0	0	0	0
0	0	0	-1	-1	-2	-2	-2	-1	-1	0	0	0
0	0	-2	-2	-3	-3	-4	-3	-3	-2	-2	0	0
0	-1	-2	-3	-3	-3	-2	-3	-3	-3	-2	-1	0
0	-1	-3	-3	-1	4	6	4	-1	-3	-3	-1	0
-1	-2	-3	-3	4	14	19	14	4	-3	-3	-2	-1
-1	-2	-4	-2	6	19	24	19	6	-2	-4	-2	-1
-1	-2	-3	-3	4	14	19	14	4	-3	-3	-2	-1
0	-1	-3	-3	-1	4	6	4	-1	-3	-3	-1	0
0	-1	-2	-3	-3	-3	-2	-3	-3	-3	-2	-1	0
0	0	-2	-2	-3	-3	-4	-3	-3	-2	-2	0	0
0	0	0	-1	-1	-2	-2	-2	-1	-1	0	0	0
0	0	0	0	0	-1	-1	-1	0	0	0	0	0

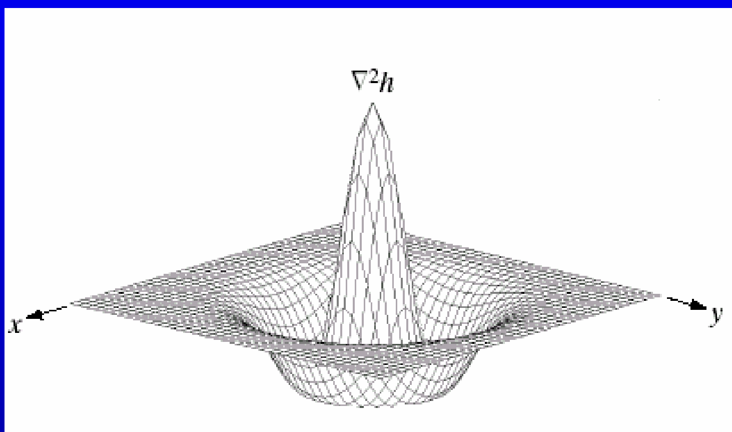
17×17 Mexican hat kernel

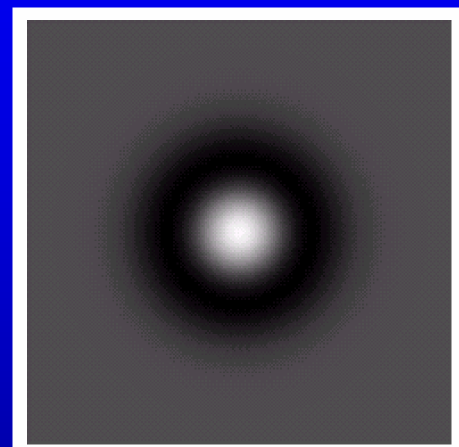
0	0	0	0	0	0	-1	-1	-1	-1	-1	0	0	0	0	0	0
0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	0	0	0
0	0	-1	-1	-1	-2	-3	-3	-3	-3	-3	-2	-1	-1	-1	0	0
0	0	-1	-1	-2	-3	-3	-3	-3	-3	-3	-3	-2	-1	-1	0	0
0	-1	-1	-2	-3	-3	-3	-2	-3	-2	-3	-3	-3	-2	-1	-1	0
0	-1	-2	-3	-3	-3	0	2	4	2	0	-3	-3	-3	-2	-1	0
-1	-1	-3	-3	-3	0	4	10	12	10	4	0	-3	-3	-3	-1	-1
-1	-1	-3	-3	-2	2	10	18	21	18	10	2	-2	-3	-3	-1	-1
-1	-1	-3	-3	-3	4	12	21	24	21	12	4	-3	-3	-3	-1	-1
-1	-1	-3	-3	-2	2	10	18	21	18	10	2	-2	-3	-3	-1	-1
-1	-1	-3	-3	-3	0	4	10	12	10	4	0	-3	-3	-3	-1	-1
0	-1	-2	-3	-3	-3	0	2	4	2	0	-3	-3	-3	-2	-1	0
0	-1	-1	-2	-3	-3	-3	-2	-3	-2	-3	-3	-3	-2	-1	-1	0
0	0	-1	-1	-2	-3	-3	-3	-3	-3	-3	-3	-2	-1	-1	0	0
0	0	-1	-1	-1	-2	-3	-3	-3	-3	-3	-2	-1	-1	-1	0	0
0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	0	0	0
0	0	0	0	0	0	-1	-1	-1	-1	-1	0	0	0	0	0	0

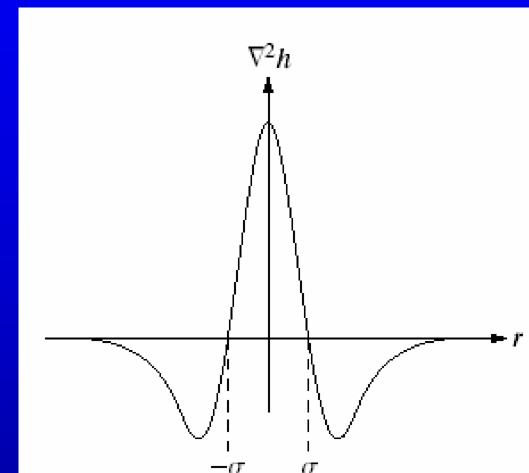




(b)





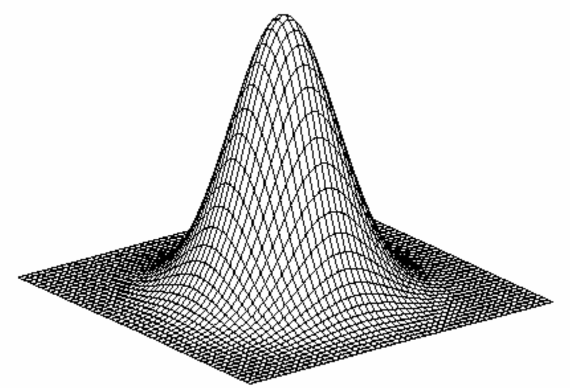


0	0	−1	0	0
0	−1	−2	−1	0
−1	−2	16	−2	−1
0	−1	−2	−1	0
0	0	−1	0	0

∇^2

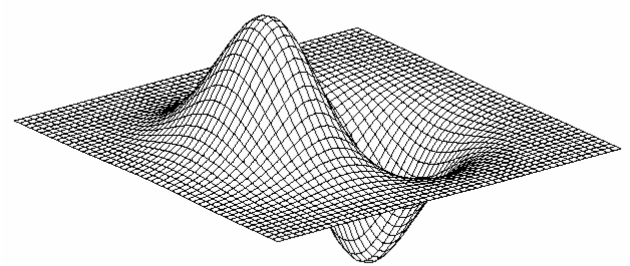
Operador Laplaciano

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$$



Gaussiana

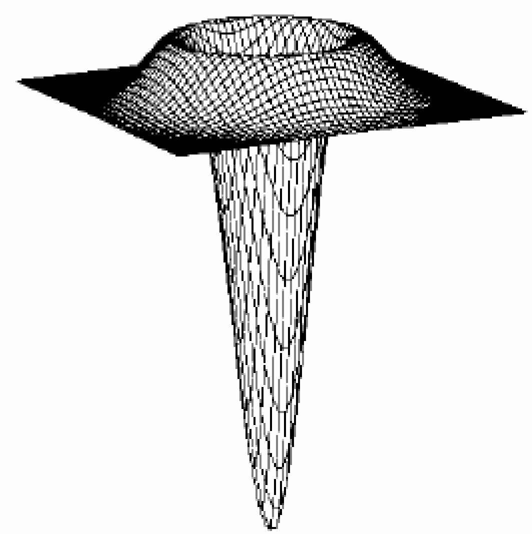
$$h_\sigma(u,v) = \frac{1}{2\pi\sigma^2} e^{-\frac{u^2+v^2}{2\sigma^2}}$$



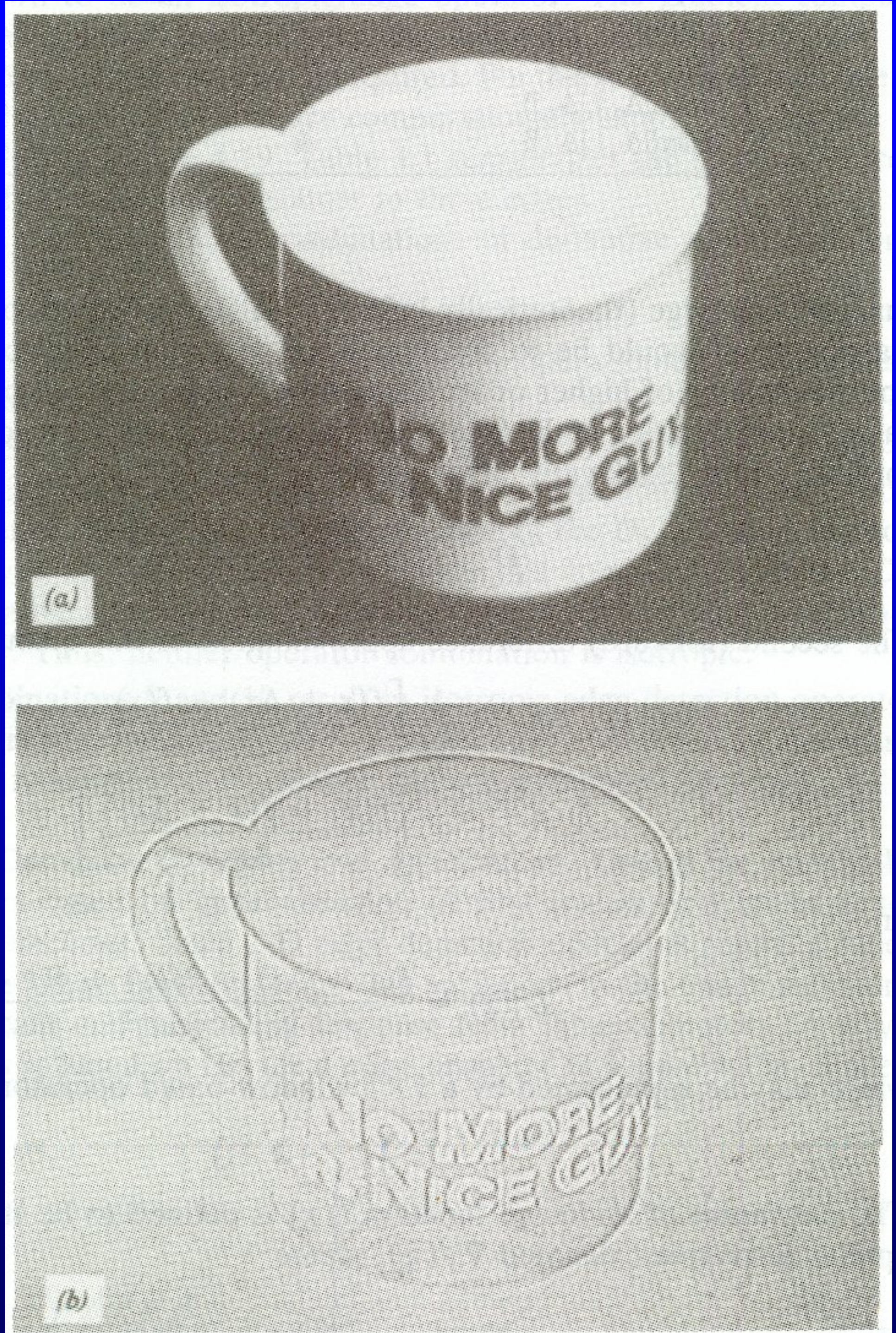
Derivada de la Gaussiana

$$\frac{\partial}{\partial x} h_\sigma(u,v)$$

LoG

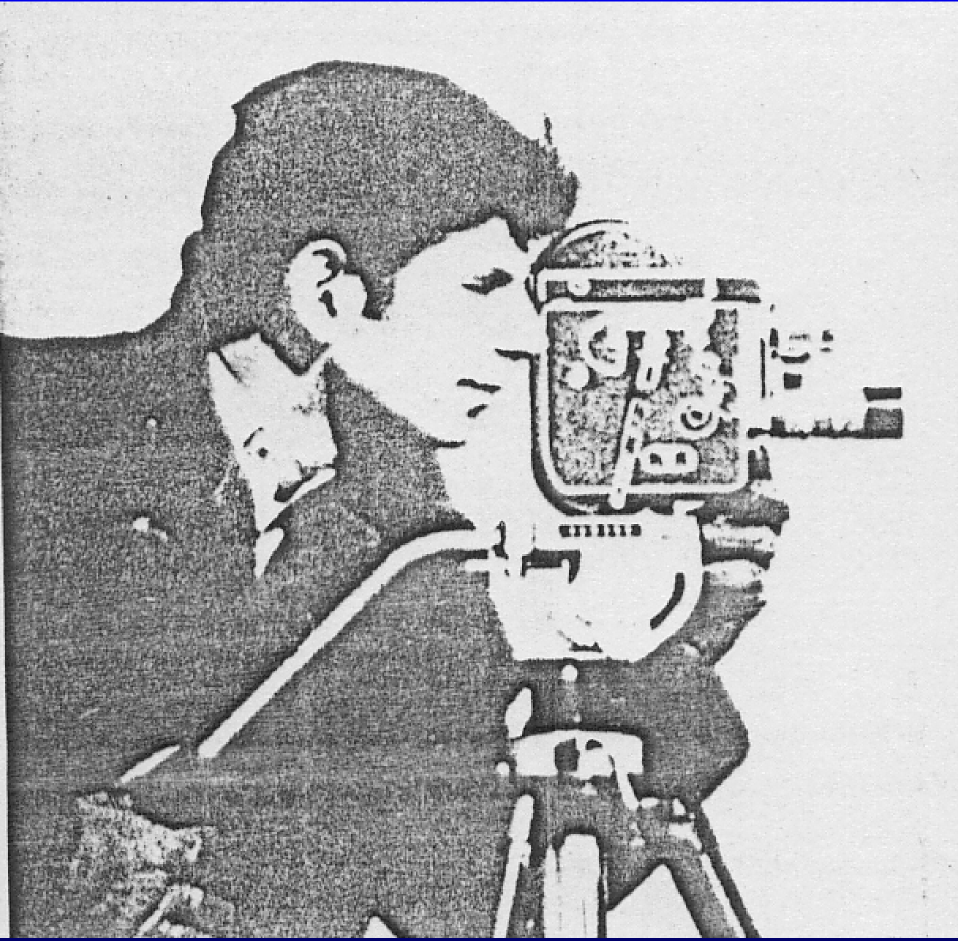


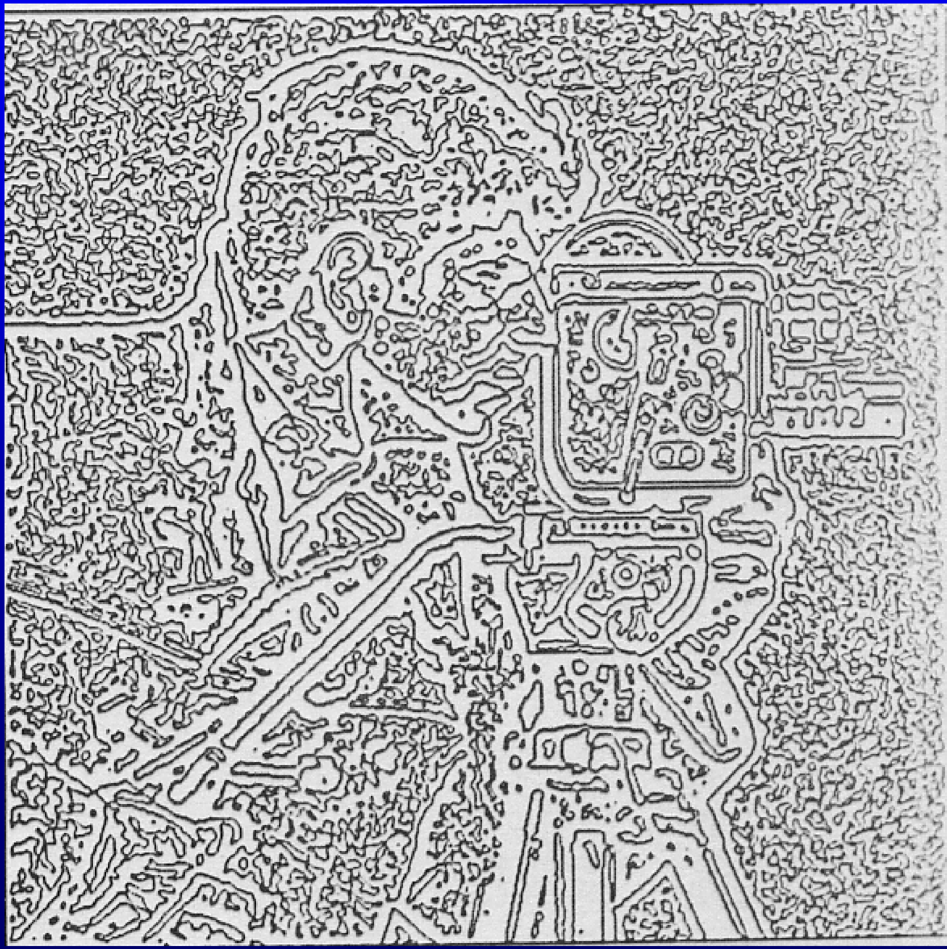
∇



Operador Laplaciano

Laplaciano y cruces por cero





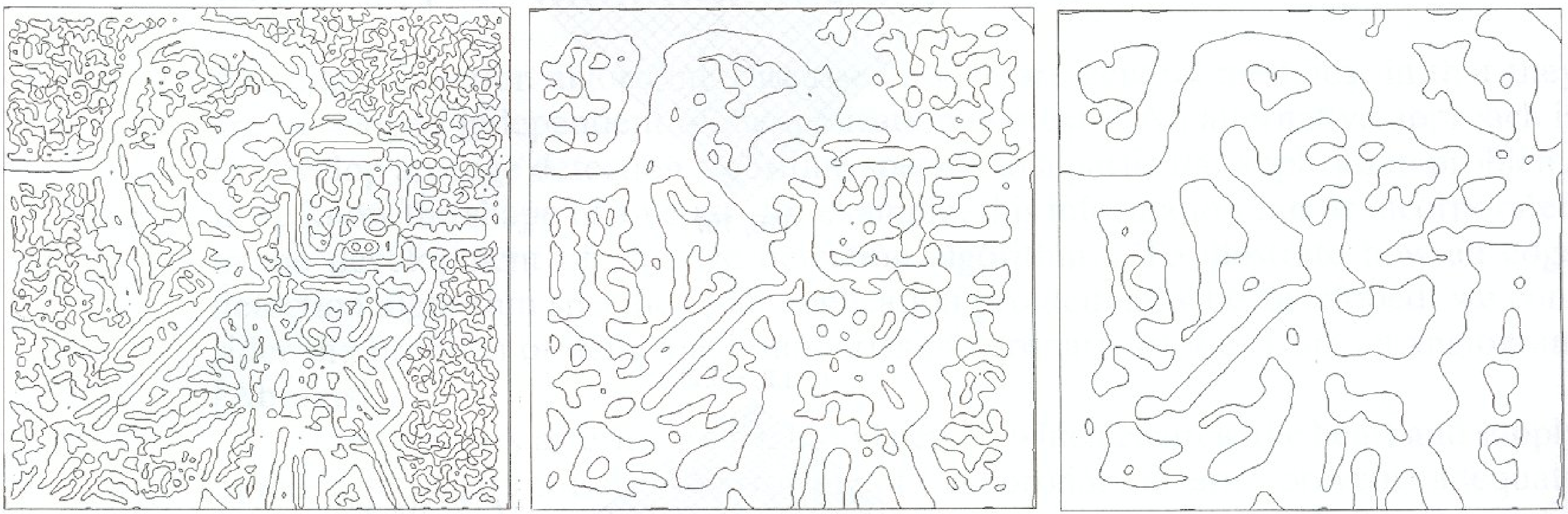
(a)

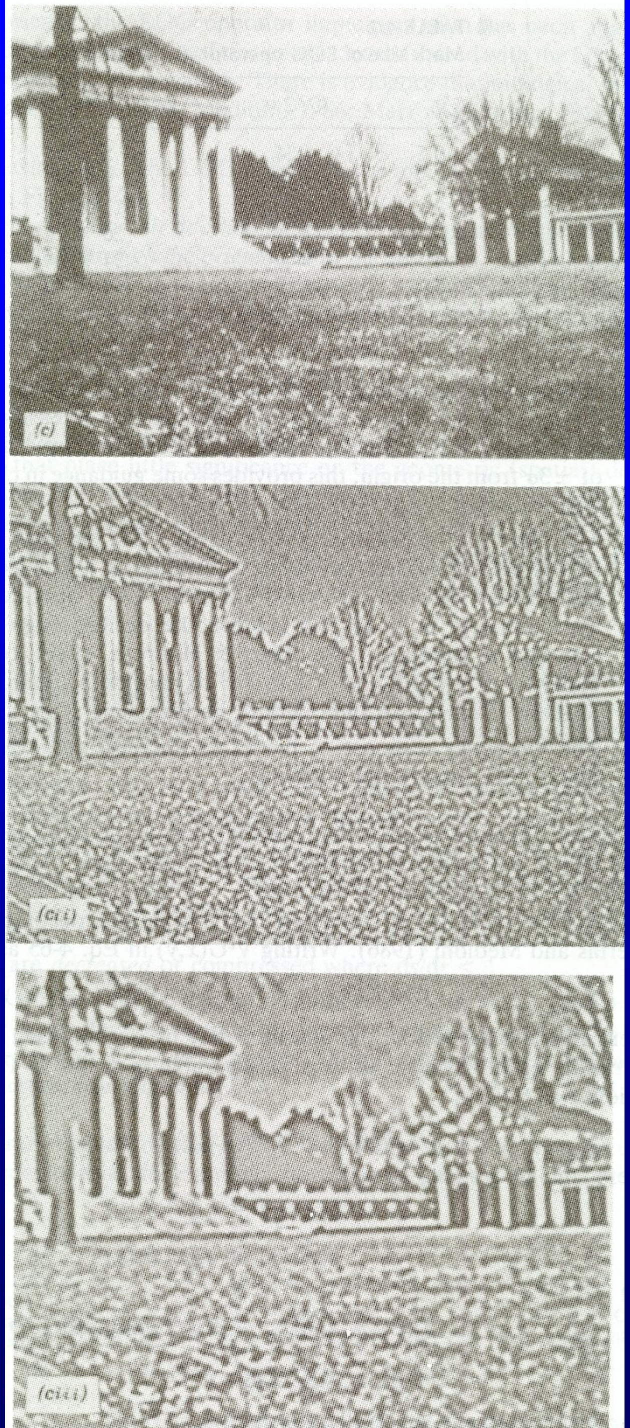
(b)

Bordes obtenidos con un detector Laplaciano y cruces por cero

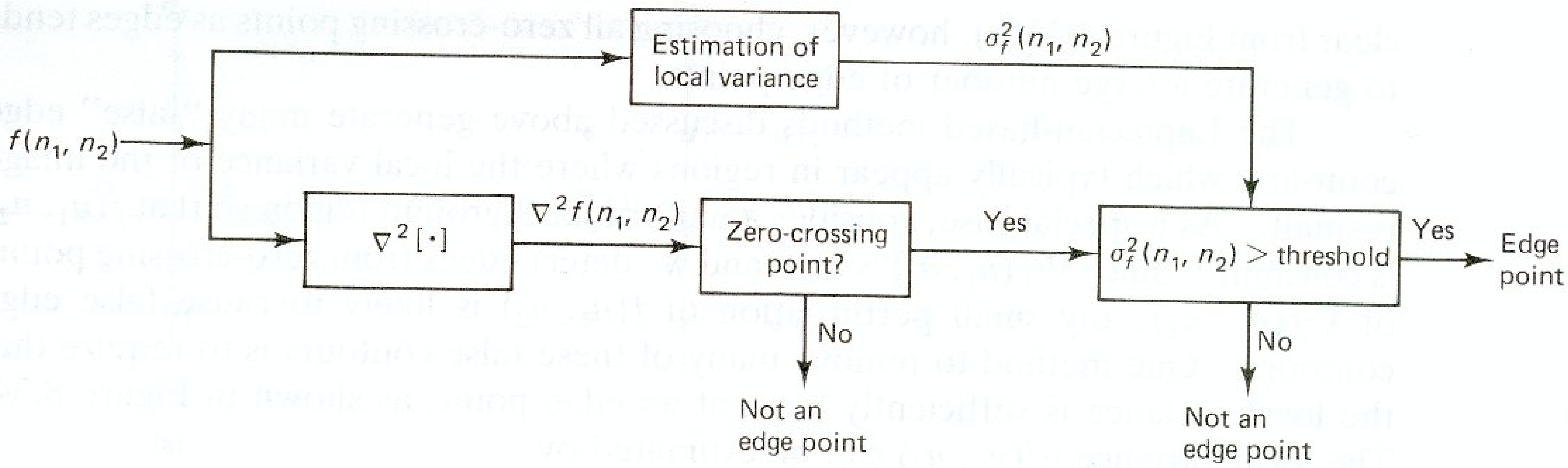
(a) (b) (c)

LoG: σ=2, σ=4, y σ=6





Operador LoG:
original
σ=0.5
σ=1.0

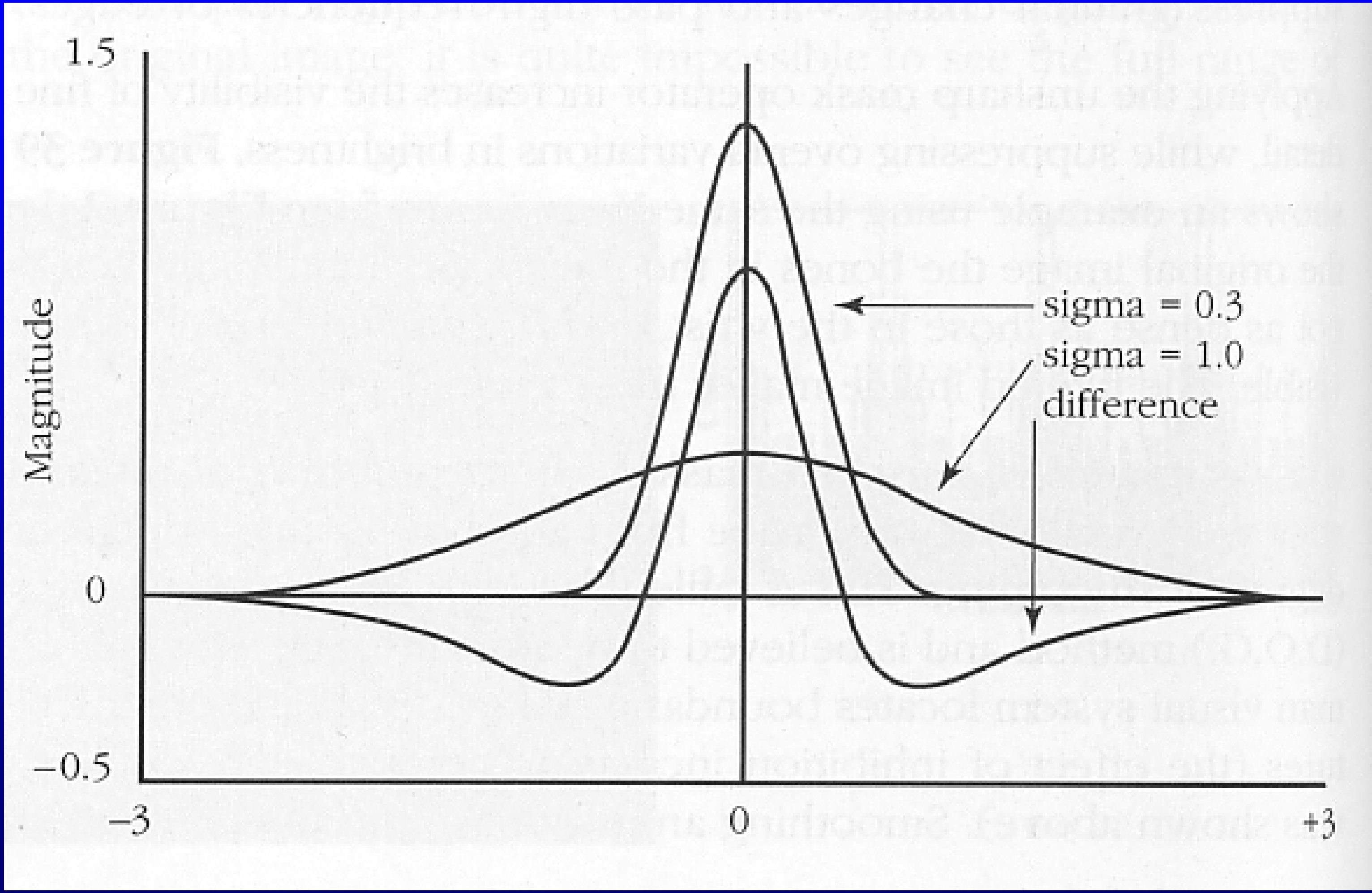

$f(n_1, n_2)$
Estimation of local variance
$\sigma_f^2(n_1, n_2)$
$\nabla^2[\cdot]$
$\nabla^2 f(n_1, n_2)$
Zero-crossing point?
Yes
No
Not an edge point
$\sigma_f^2(n_1, n_2) > \text{threshold}$
Yes
Edge point
No
Not an edge point

(a)

(b)

Bordes con Laplaciano cruces por cero y umbral en base a varianza local

DoG



(a)

Laplacian filter of bone scan (a)

(b)

Sharpened version of bone scan achieved by subtracting (a) and (b)

(c)

Sobel filter of bone scan (a)

(d)

(e)

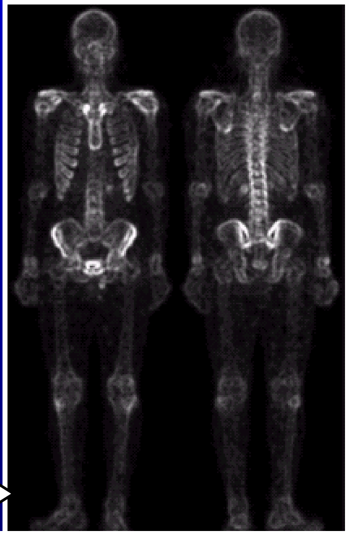
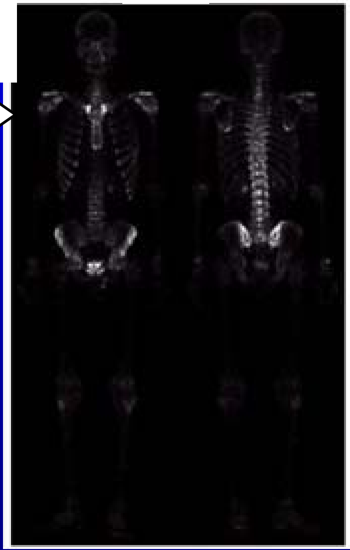


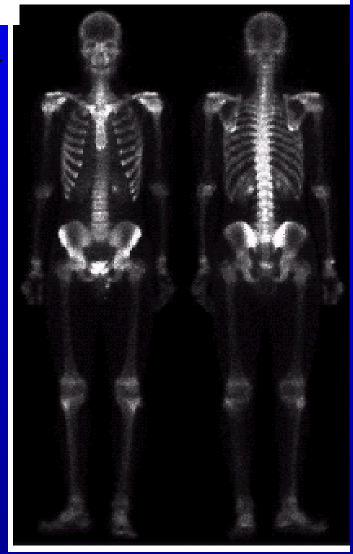
Image (d) smoothed with a 5*5 averaging filter

(f)



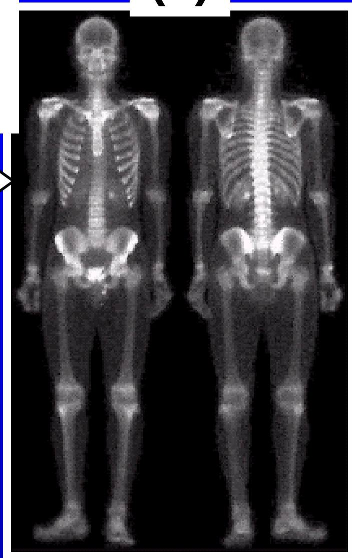
The product of (c) and (e) which will be used as a mask

(g)



Sharpened image which is sum of (a) and (f)

(h)



Result of applying a power-law trans. to (g)