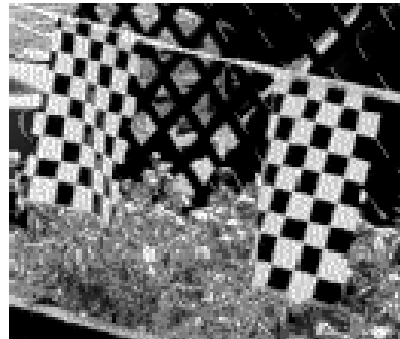


# 5º CAPÍTULO

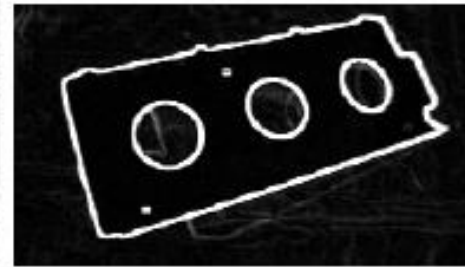
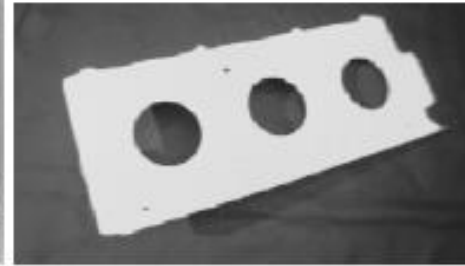
## Pré-Processamento de Imagem



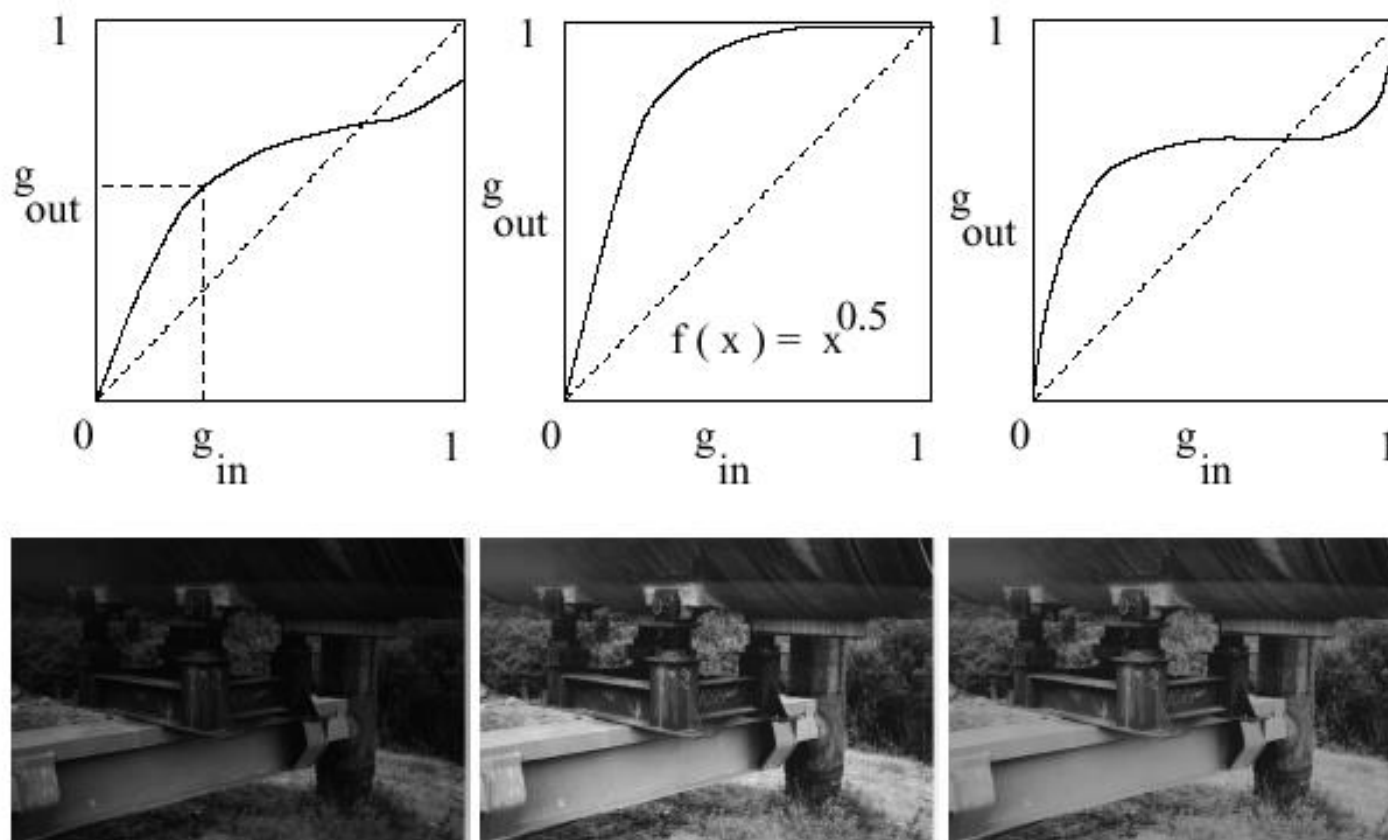
Prof. Arnaldo Abrantes

# Necessidade de pré-processamento

---

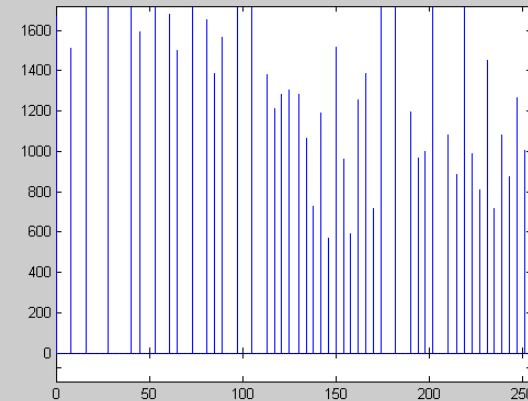
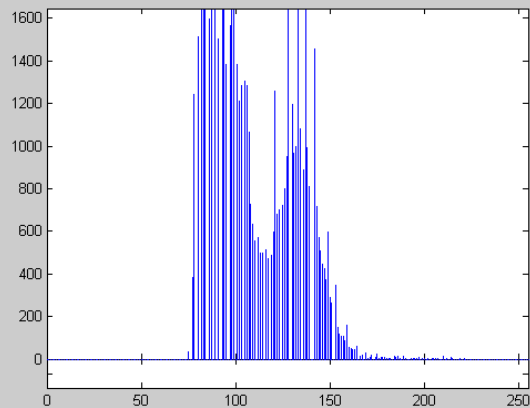


# Transformação de níveis de cinzento



- Correção gama  $\longrightarrow f(x) = O_{\min} + \frac{O_{\max} - O_{\min}}{(I_{\max} - I_{\min})^\gamma} (x - I_{\min})^\gamma$

# Equalização de histograma



# Remover pequenas regiões



← Remoção de ruído salt & pepper

1	1	1
1	0	1
1	1	1

⇒

1	1	1
1	1	1
1	1	1

;

0	0	0
0	1	0
0	0	0

⇒

0	0	0
0	0	0
0	0	0

X	X	X
X	L	X
X	X	X

⇒

X	X	X
X	X	X
X	X	X

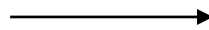
;

	X	
X	L	X
	X	

⇒

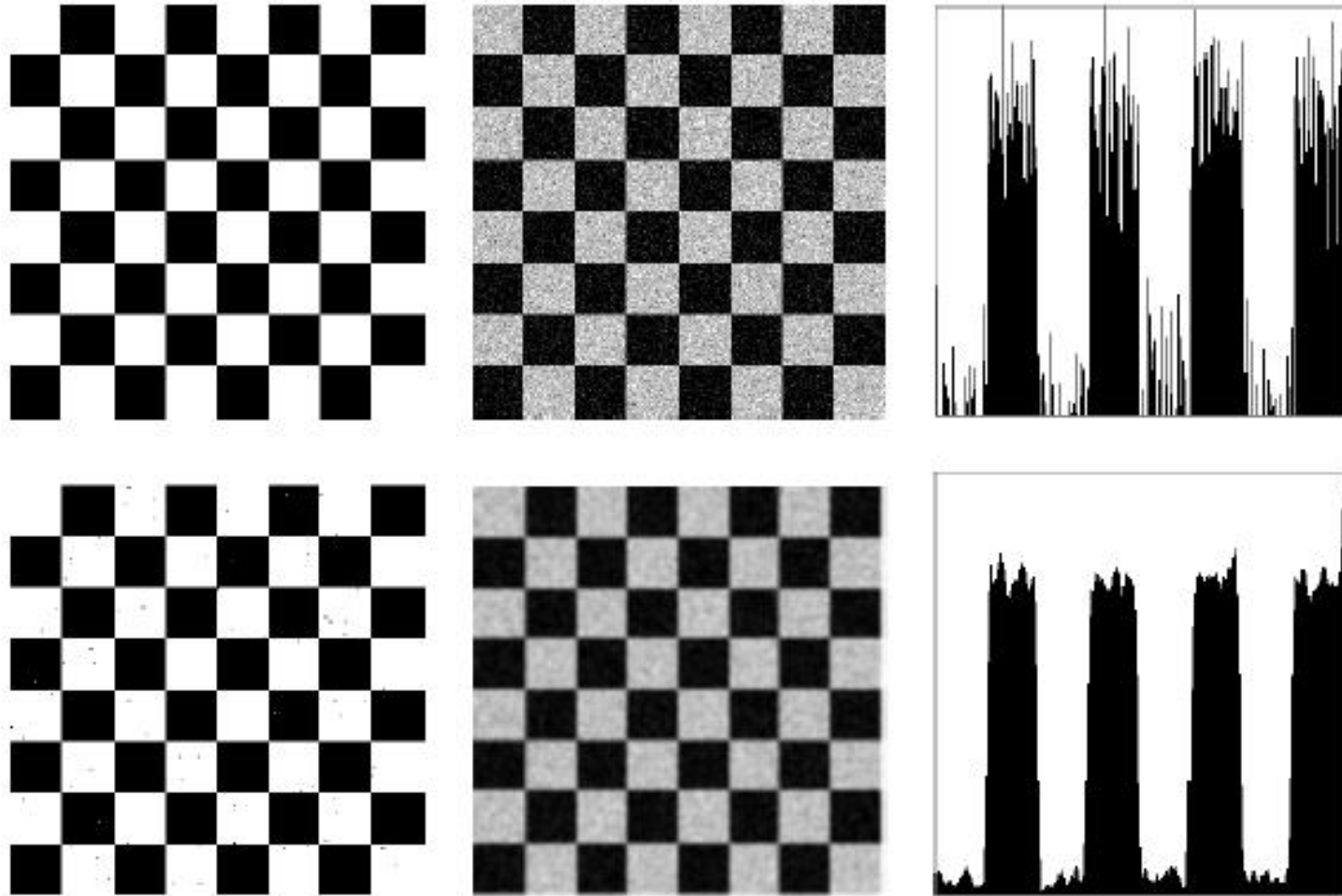
	X	
X	X	X
	X	

Remoção de componentes conexos  
cuja área é pequena



# Necessidade de operação de suavização

---



- Suavização (filtragem passa-baixo) de imagem
  - filtro de média (*box filter*)

$$O(r, c) = \left( \sum_{i=-N}^N \sum_{j=-N}^N I(r+i, c+j) \right) / (2N+1)^2$$

- filtro gaussiano

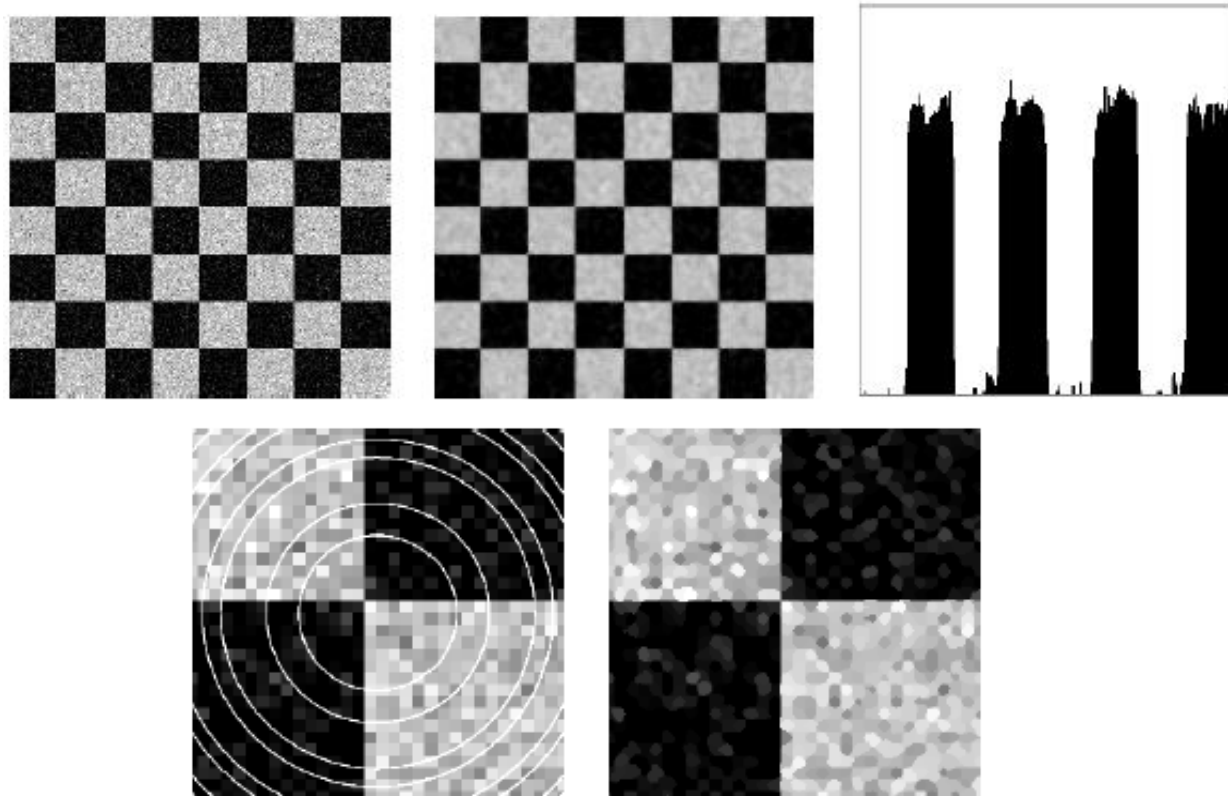
$$O(r, c) = \sum_{i=-N}^N \sum_{j=-N}^N g(i, j) I(r+i, c+j)$$

$$g(x, y) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{d^2}{2\sigma^2}}$$

$$d = \sqrt{(x - x_c)^2 + (y - y_c)^2}$$

- Seja  $A[i]_{i=0, \dots, n-1}$  uma lista ordenada de números reais. A *mediana* do conjunto  $\mathbf{A}$  é o valor  $A[(n-1)/2]$

– Exemplos





# Filtragem temporal com filtro de mediana

---



Filtragem de Mediana da Sequência



**Compute output image pixel  $G[r,c]$  from neighbors of input image pixel  $F[r,c]$ .**

**$F[r,c]$**  is an input image of MaxRow rows and MaxCol columns;

**$F$**  is unchanged by the algorithm.

**$G[r,c]$**  is the output image of MaxRow rows and MaxCol columns.

The border of  **$G$**  are all those pixels whose neighborhoods  
are not wholly contained in  **$G$** .

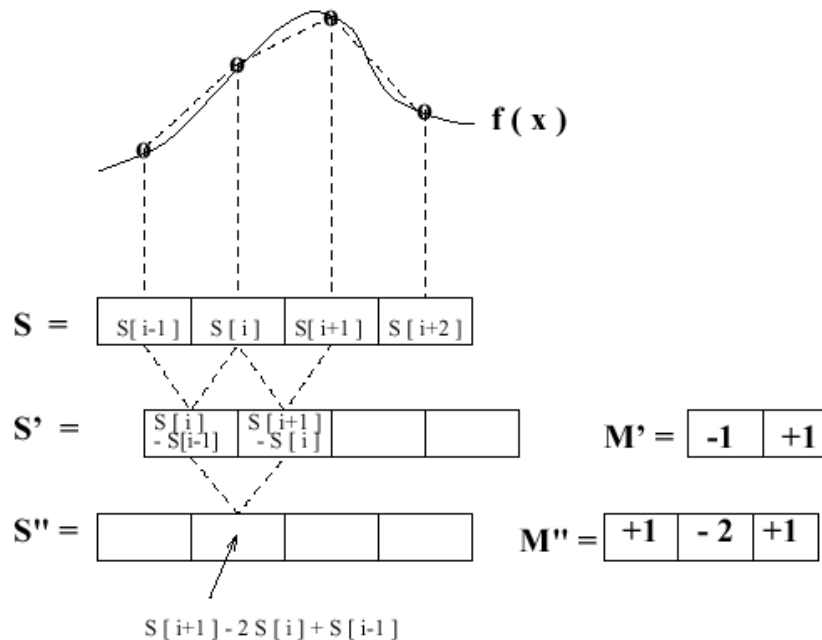
$w$  and  $h$  are the width and height, in pixels, defining a neighborhood.

```
procedure enhance_image(F,G,w,h);
{
  for r := 0 to MaxRow - 1
    for c := 0 to MaxCol - 1
      {
        if [r,c] is a border pixel then G[r,c] := F[r,c];
        else G[r,c] := compute_using_neighbors ( F, r, c, w, h );
      };
}
procedure compute_using_neighbors ( IN, r, c, w, h )
{
  using all pixels within w/2 and h/2 of pixel IN[r,c],
  compute a value to return to represent IN[r,c]
}
```

# Detecção de transições (*edges*)

- Operadores diferenciais de sinais 1D

$$f'(x_i) \approx \frac{f(x_i) - f(x_{i-1})}{x_i - x_{i-1}}$$



Máscara 1D centrada



mask  $M = [-1, 0, 1]$

$S_1$			12	12	12	12	12	24	24	24	24	24
$S_1$	$\otimes$	$M$	0	0	0	0	12	12	0	0	0	0

(a)  $S_1$  is an upward step edge

$S_2$			24	24	24	24	24	12	12	12	12	12
$S_2$	$\otimes$	$M$	0	0	0	0	-12	-12	0	0	0	0

(b)  $S_2$  is a downward step edge

$S_3$			12	12	12	12	15	18	21	24	24	24
$S_3$	$\otimes$	$M$	0	0	0	3	6	6	6	3	0	0

(c)  $S_3$  is an upward ramp

$S_4$			12	12	12	12	24	12	12	12	12	12
$S_4$	$\otimes$	$M$	0	0	0	12	0	-12	0	0	0	0

(d)  $S_4$  is a bright impulse or "line"

mask  $M = [-1, 2, -1]$

$S_1$			12	12	12	12	12	24	24	24	24	24
$S_1$	$\otimes$	$M$	0	0	0	0	-12	12	0	0	0	0

(a)  $S_1$  is an upward step edge

$S_2$			24	24	24	24	24	12	12	12	12	12
$S_2$	$\otimes$	$M$	0	0	0	0	12	-12	0	0	0	0

(b)  $S_2$  is a downward step edge

$S_3$			12	12	12	12	15	18	21	24	24	24
$S_3$	$\otimes$	$M$	0	0	0	-3	0	0	0	3	0	0

(c)  $S_3$  is an upward ramp

$S_4$			12	12	12	12	24	12	12	12	12	12
$S_4$	$\otimes$	$M$	0	0	0	-12	24	-12	0	0	0	0

(d)  $S_4$  is a bright impulse or "line"

box smoothing mask  $M = [1/3, 1/3, 1/3]$

$S_1$			12	12	12	12	12	24	24	24	24	24
$S_1$	$\otimes$	$M$	12	12	12	12	16	20	24	24	24	24

(a)  $S_1$  is an upward step edge

$S_4$			12	12	12	12	24	12	12	12	12	12
$S_4$	$\otimes$	$M$	12	12	12	16	16	16	12	12	12	12

(d)  $S_4$  is a bright impulse or "line"

Gaussian smoothing mask  $M = [1/4, 1/2, 1/4]$

$S_1$			12	12	12	12	12	24	24	24	24	24
$S_1$	$\otimes$	$M$	12	12	12	12	15	21	24	24	24	24

(a)  $S_1$  is an upward step edge

$S_4$			12	12	12	12	24	12	12	12	12	12
$S_4$	$\otimes$	$M$	12	12	12	15	18	15	12	12	12	12

- Operadores diferenciais
  - as coordenadas das máscaras tem sinais opostos para que se obtenha uma resposta máxima quando existem transições de intensidade (contraste)
  - A soma dos valores é zero para que a resposta seja zero quando a região é constante
  - As máscaras de primeira derivada produzem valores absolutos elevados em pontos de grande contraste
  - As máscaras de segunda derivada produzem cruzamentos por zero em pontos de grande contraste
- Operadores de suavização
  - os elementos da máscara são positivos e somam um, de modo a que a saída é igual à entrada em regiões de constante intensidade
  - A quantidade de suavização e remoção de ruído é proporcional à dimensão da máscara
  - Transições abruptas (step edges) são tanto mais espalhadas (blurred) quanto maior for a dimensão da máscara

# Operadores diferenciais 2D

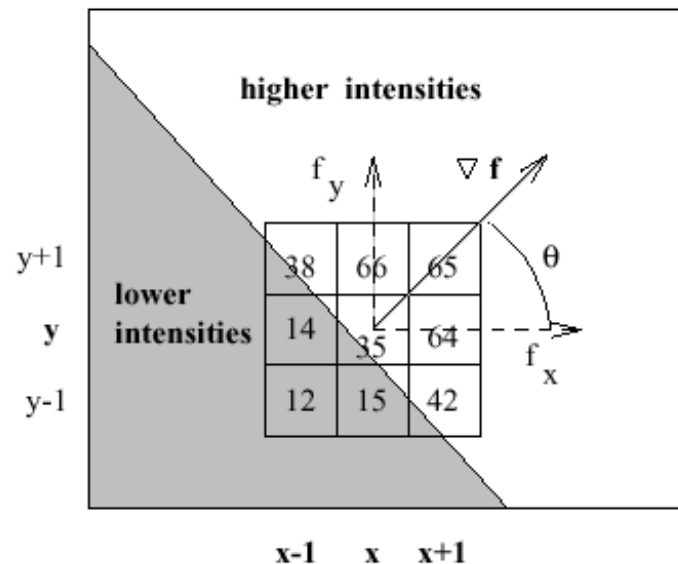
- Gradiente duma função

$$\nabla f = \left( \frac{\partial f}{\partial x}, \frac{\partial f}{\partial y} \right)$$

$$|\nabla f| \approx \sqrt{f_x^2 + f_y^2}$$

$$\theta \approx \tan^{-1}(f_y / f_x)$$

Exemplo:



$$\begin{aligned} f_y &= ((38-12)/2 + (66-15)/2 \\ &\quad + (65-42)/2) / 3 \\ &= (13 + 25 + 11) / 3 = 16 \end{aligned}$$

$$\begin{aligned} f_x &= ((65-38)/2 + (64-14)/2 \\ &\quad + (42-12)/2) / 3 \\ &= (13 + 25 + 15) / 3 = 18 \end{aligned}$$

$$\begin{aligned} \theta &= \tan^{-1}(16 / 18) = 0.727 \text{ rad} \\ &= 42 \text{ degrees} \end{aligned}$$

$$|\nabla f| = (16^2 + 18^2)^{1/2} = 24$$

# Detectores de pontos de contorno

**Prewitt:**  $M_x = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} ; M_y = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix}$

**Sobel:**  $M_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} ; M_y = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$

**Roberts:**  $M_x = \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix} ; M_y = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$



(a)



(b)



(c)



(d)



(e)



(f)

# Detector de contornos de Canny

---



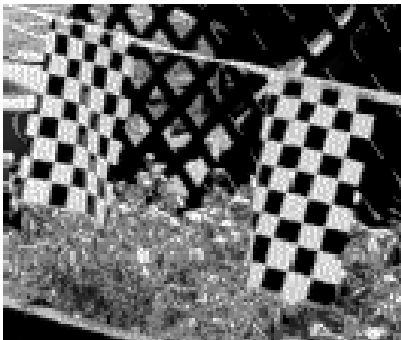
Original



Canny ( $\sigma = 1$ )



Canny ( $\sigma = 4$ )



Original



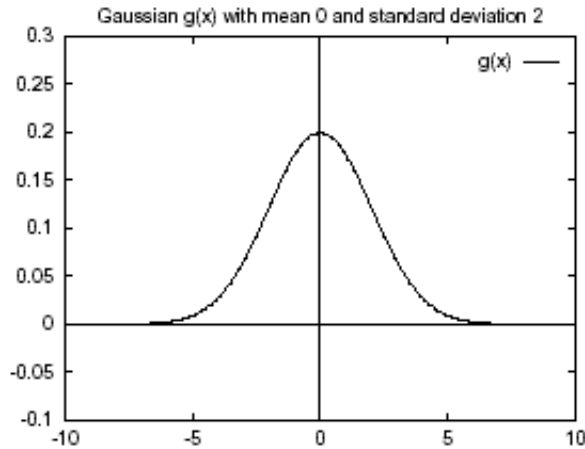
Canny ( $\sigma = 1$ )



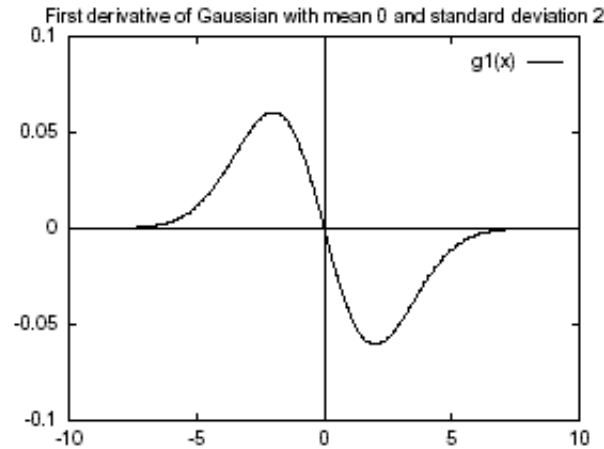
Roberts (20%)



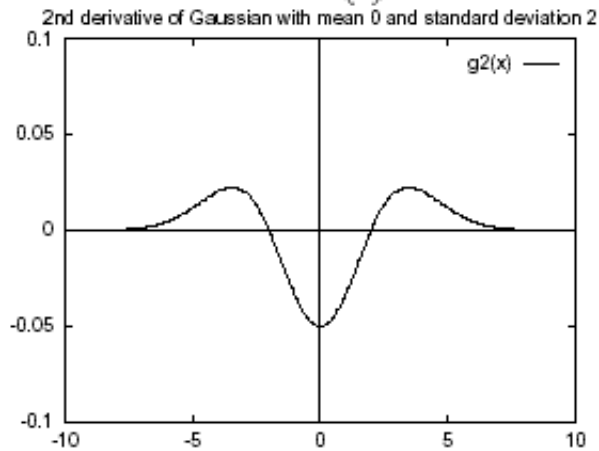
# Filtros gaussianos



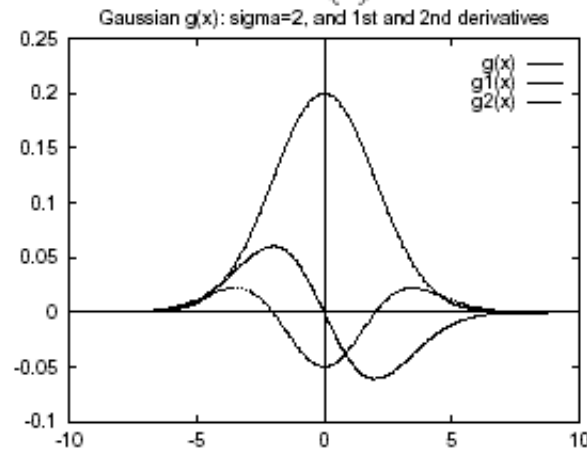
(a)



(b)



(c)



(d)

Caso 1D:

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

$$g'(x) = \frac{-x}{\sigma^2} g(x)$$

$$g''(x) = \left( \frac{x^2}{\sigma^4} - \frac{1}{\sigma^2} \right) g(x)$$

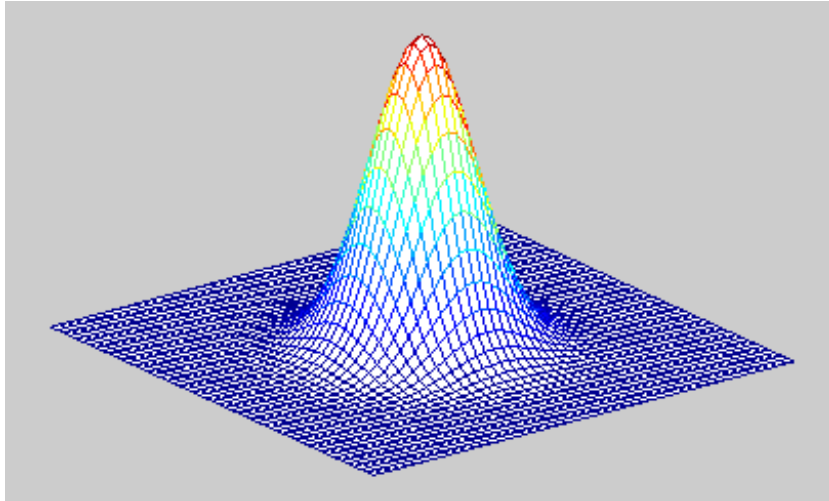
Caso 2D:

$$h(x, y) = g(r)$$

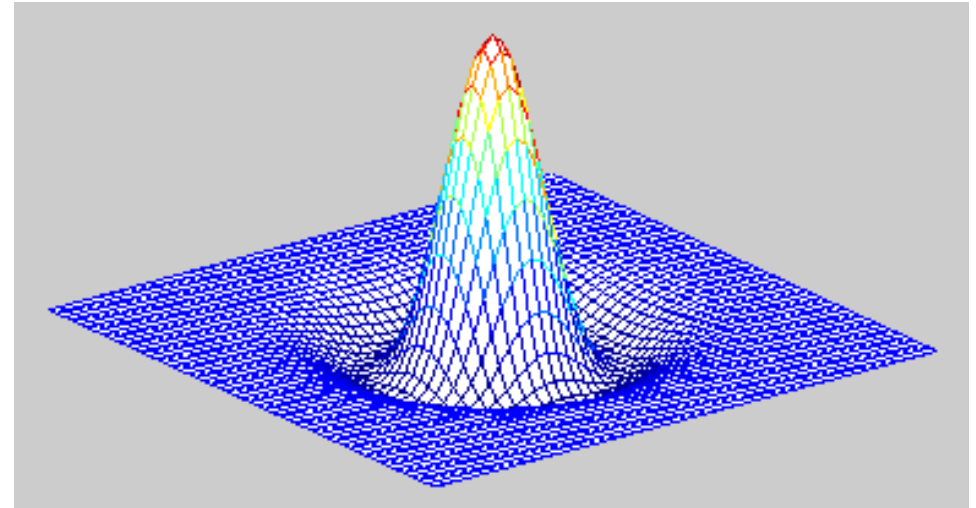
$$r = \sqrt{x^2 + y^2}$$

# Detector de edges baseado na função Laplaciana – filtro LOG

$g(x, y)$



$$L(x, y) = \frac{\partial^2 g(x, y)}{\partial x^2} + \frac{\partial^2 g(x, y)}{\partial y^2}$$



$-L(x, y) \longrightarrow$  Chapéu mexicano (*sombrero*)

$\longleftarrow$  Máscara 11x11 ( $\sigma^2=2$ )

0	0	0	-1	-1	-2	-1	-1	0	0	0
0	0	-2	-4	-8	-9	-8	-4	-2	0	0
0	-2	-7	-15	-22	-23	-22	15	-7	-2	0
-1	-4	-15	-24	-14	-1	-14	-24	-15	-4	-1
-1	-8	-22	-14	52	103	52	-14	-22	-8	-1
-2	-9	-23	-1	103	178	103	-1	-23	-9	-2
-1	-8	-22	-14	52	103	52	-14	-22	-8	-1
-1	-4	-15	-24	-14	-1	-14	-24	-15	-4	-1
0	-2	-7	-15	-22	-23	-22	15	-7	-2	0
0	0	-2	-4	-8	-9	-8	-4	-2	0	0
0	0	0	-1	-1	-2	-1	-1	0	0	0



- 
- The diagram illustrates the receptive field overlap between two neurons, A and B, across two levels: the retinal level and the integrating level.
- Retinal Level:**
- Receptive Field for Neuron A:** A large circle containing points 'a', 'b', and 'c'. It is labeled "receptive field for neuron A".
  - Receptive Field for Neuron B:** A large circle containing points 'd', 'e', and 'f'. It is labeled "receptive field for neuron B".
  - Intensity Edge:** A dashed line separates the two receptive fields, labeled "intensity edge".
  - Retinal Level:** The area between the two receptive fields, containing points 'a', 'b', 'c', 'd', 'e', and 'f'. It is labeled "retinal level".
  - Connections:** Lines connect points 'a', 'b', and 'c' to neuron A, and points 'd', 'e', and 'f' to neuron B. The connections from 'a' and 'b' are labeled with '+' signs, while the connection from 'c' is labeled with a '-' sign. The connections from 'd' and 'e' are labeled with '+' signs, while the connection from 'f' is labeled with a '-' sign.
- Integrating Level:**
- Neuron A:** A circle labeled "A" that receives input from the retinal level. It is labeled "integrating level".
  - Neuron B:** A circle labeled "B" that receives input from the retinal level. It is labeled "integrating level".

- Filtro LOG ajuda a explicar o SVH (baixo nível)
  - Objectivo primeiro é a construção do esboço fundamental (*primal sketch: lines, edges, blobs*)
- Análise multiresolução
  - filtragem LOG, com elevado  $\sigma$ , permite a detecção das estruturas principais existentes na imagem, enquanto que os detalhes se obtêm fazendo o processamento com  $\sigma$  pequeno.



original



smoothed  $\sigma = 4$



smoothed  $\sigma = 1$

# Agrupamento perceptual - linhas virtuais

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Linhas virtuais em imagens reais