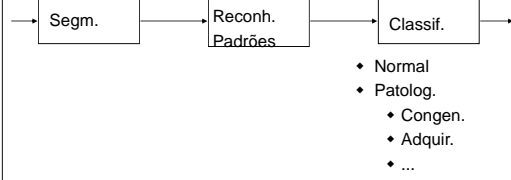


Segmentação de Imagens

Motivação

- Identificação de objetos
- Quantização: contagens, área, perímetro, volume
- Visualização 2D, 3D
- Reconhecimento de padrões
- Classificação

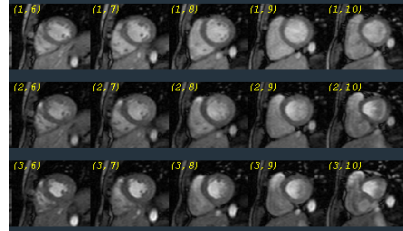


Segmentação de Imagens

S.Furulo /EPUSP-1

Motivação

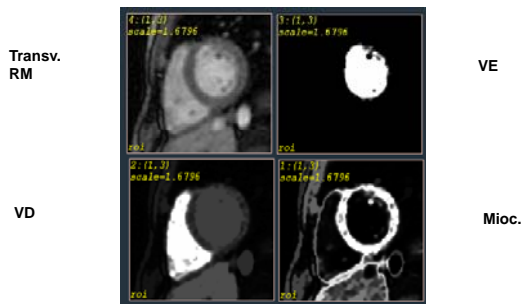
- Processos convencionais (manual e semi-automático) : demorados e cansativos
 - gated MRI : 16 volumes, 12 cortes => 192 img
 - gated SPECT: idem



Segmentação de Imagens

S.Furulo /EPUSP-2

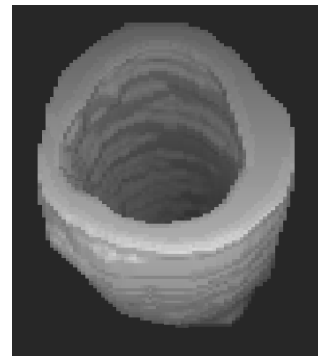
Resultados em RM



Segmentação de Imagens

S.Furulo /EPUSP-3

VE: pre-Ventriculotomia

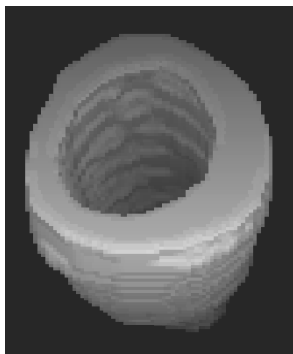


Diástole

Segmentação de Imagens

S.Furulo /EPUSP-4

VE: pre-ventriculotomia



Sístole

Segmentação de Imagens

S.Furulo /EPUSP-5

Como proceder p/ segmentar?

**QUAIS CARACTERÍSTICAS
EXPLORAR?**

Segmentação de Imagens

S.Furulo /EPUSP-6

Visão Global

- Operadores
- Representação dos resultados da segmentação
- Técnicas de segmentação
 - thresholding
 - snakes
 - region-growing
 - split-merge
 - fuzzy connectedness
 - redes neurais
 - métodos estatísticos
- Interpretação

Segmentação de Imagens

S.Furuiê /EPUSP-7

Segmentação de Imagens

- Por descontinuidade
 - operadores (detetores)
 - ponto
 - linha
 - borda (gradiente, laplaciano e LoG)
 - Contornos
 - manual
 - semi-automático
 - automático (conexão de bordas, Transf. de Hough)
- Por similariedade
 - thresholding
 - region-growing
 - split and merge

Segmentação de Imagens

S.Furuiê /EPUSP-8

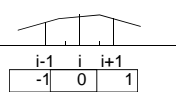
Gradiente

$$\nabla f(x, y) = \frac{\partial f(x, y)}{\partial x} u_x + \frac{\partial f(x, y)}{\partial y} u_y$$

$$\left. \frac{\partial f(x, y)}{\partial x} \right|_{x-1} = f(i + \frac{1}{2}) - f(i - \frac{1}{2})$$

$$f(i + \frac{1}{2}) = \frac{f(i) + f(i+1)}{2}$$

$$f(i - \frac{1}{2}) = \frac{f(i-1) + f(i)}{2}$$

$$\left. \frac{\partial f(x, y)}{\partial x} \right|_{x-1} = \frac{f(i+1) - f(i-1)}{2}$$


$\frac{\partial f(x, y)}{\partial x}$	-1	0	1	-1	0	1
$\frac{\partial f(x, y)}{\partial y}$	-1	-1	-1	-1	-2	-1
	0	0	0	0	0	0
	1	1	1	1	2	1

Segmentação de Imagens

S.Furuiê /EPUSP-9

Algoritmo p/ Laplaciano em x?

$$\left. \frac{\partial f(x, y)}{\partial x} \right|_{x-1} = f(i + \frac{1}{2}) - f(i - \frac{1}{2})$$

$$f(i + \frac{1}{2}) = \frac{f(i) + f(i+1)}{2}$$

$$f(i - \frac{1}{2}) = \frac{f(i-1) + f(i)}{2}$$

$$\left. \frac{\partial f(x, y)}{\partial x} \right|_{x-1} = \frac{f(i+1) - f(i-1)}{2}$$

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

Segmentação de Imagens

S.Furuiê /EPUSP-10

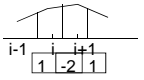
Sobel, Laplace,...

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

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

$$\left. \frac{\partial^2 f(x, y)}{\partial x^2} \right|_i = \frac{\partial}{\partial x} \left(\frac{\partial f}{\partial x} \right) = \left(\frac{\partial f}{\partial x} \right)_{i+\frac{1}{2}} - \left(\frac{\partial f}{\partial x} \right)_{i-\frac{1}{2}}$$

$$= (f(i+1) - f(i)) - (f(i) - f(i-1))$$

$$= f(i-1) - 2f(i) + f(i+1)$$


0	1	0
1	-4	1
0	1	0

H(z) = (z⁻¹ - 2 + z)

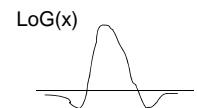
H(w) = -2(1 - cos(wT))

Segmentação de Imagens

S.Furuiê /EPUSP-11

Laplaciano da Gaussiana (LoG)

- Edge detector
 - Gauss=>Smooth
 - Laplace=>Zero crossing



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

$$g(x, y) = \nabla^2 Gauss(x, y) * f(x, y)$$

Segmentação de Imagens

S.Furuiê /EPUSP-12

Segmentação por região

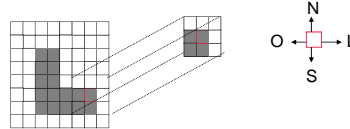
- ☞ Região: Region-growing
 - conectividade, afinidade, tamanho, forma, possibilidade
 - semente
 - para cada vizinho, agregar o mesmo se similar. Se agregado, considerar os vizinhos deste.
- ☞ Região: Split and Merge
 - quadtree, octree
 - testar homogeneidade de cada quadrante
 - se não homogêneo, subdividir e continuar até último quadrante
 - merge de quadrantes vizinhos com homogeneidades similares.

Segmentação de Imagens

S.Furuié /EPUSP- 13

Região: Region-growing

- conectividade, afinidade, tamanho, forma, possibilidade
 - semente
 - para cada vizinho não visitado, agregar o mesmo se similar. Se agregado, considerar os vizinhos deste (usar fila)



• extensão p/ tons de cinza e 3D

Segmentação de Imagens

S.Furuié /EPUSP- 14

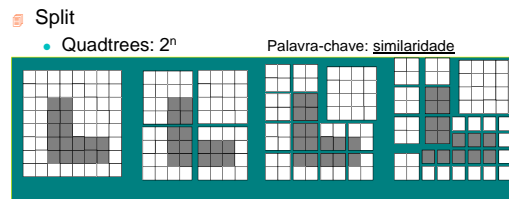
Região: Split and Merge

- quadtree, octree
 - testar homogeneidade de cada quadrante
 - se não homogêneo, subdividir e continuar até último quadrante
 - merge de quadrantes vizinhos com homogeneidades similares.

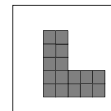
Segmentação de Imagens

S.Furuié /EPUSP- 15

Split and Merge



- Merge (p. ex. labeling)
- Estender p/ tons de cinza
- Estender p/ 3D



Segmentação de Imagens

S.Furuié /EPUSP- 16

Thresholding: Efeito do ruído no histograma

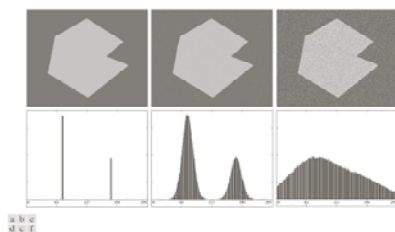


FIGURE 10.34 (a) Noiseless 8-bit image. (b) Image with additive Gaussian noise of mean 0 and standard deviation of 10 intensity levels. (c) Image with additive Gaussian noise of mean 0 and standard deviation of 50 intensity levels. (d)-(f) Corresponding histograms.

Segmentação de Imagens

S.Furuié /EPUSP- EX.

Técnicas: Thresholding

- ☞ $T = T[f(x,y), x, y, p(x,y)]$
 - de imagem $f(x,y)$
 - $p(x,y)$: propriedade local
- ☞ Global
- ☞ Ótimo:
- ☞ local : baseado na região das bordas
- ☞ baseado em características: grad. e laplaciano
- ☞ multi-banda

$$\min_T \text{Erro}(T)$$

$$\text{Erro}(T) = P_2 \int_0^T p_2(x) dx + P_1 \int_T^1 p_1(x) dx$$

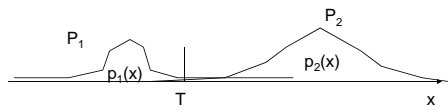
$$\frac{\partial \text{Erro}(T)}{\partial T} = 0 \Rightarrow P_1 \cdot p_1(T) = P_2 \cdot p_2(T)$$

$p_1(x), p_2(x)$: se Gaussian

$$T = \frac{\mu_1 + \mu_2}{2} + \frac{\sigma^2}{\mu_1 - \mu_2} \ln \left(\frac{P_2}{P_1} \right)$$

S.Furuié /EPUSP- 18

Optimal thresholding



$$p(x) = P_1 \cdot p_1(x) + P_2 \cdot p_2(x)$$

$$p_1(x) = \frac{1}{\sqrt{2\pi}\sigma_1} \exp\left(-\frac{(x-\mu_1)^2}{2\sigma_1^2}\right)$$

$$P_1 + P_2 = 1$$

$$\text{Erro} = P_2 \cdot \int_{-\infty}^T p_2(x) \cdot dx + P_1 \cdot \int_T^{\infty} p_1(x) \cdot dx$$

$$\min_T \text{Erro} \Rightarrow \frac{\partial \text{Erro}}{\partial T} = 0$$

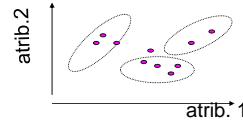
$$\Rightarrow P_1 \cdot p_1(T) = P_2 \cdot p_2(T)$$

$$T = \frac{\mu_1 + \mu_2}{2} + \frac{\sigma_1^2 - \sigma_2^2}{\mu_1 - \mu_2} \ln\left(\frac{P_2}{P_1}\right)$$

Segmentação de Imagens

S.Furuiê /EPUSP-19

Isodata (k-means)



0) K classes com centro em c_j

1) Inicializar $c_j^{(0)}$
2) Para cada $x_i \Rightarrow$ atribuir x_i p / classe j com menor distancia

3) Recalcular c_j

4) Repetir 2) e 3) ate nao haver mais alter.

Segmentação de Imagens

S.Furuiê /EPUSP-20

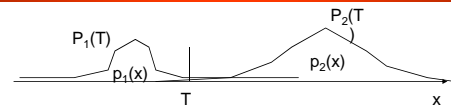
Técnicas: Thresholding por Otsu

- Global
- Baseado no histograma
- Ótimo para casos discretos (intensidade): maximiza a separabilidade entre classes
- Definição de separabilidade ?

Segmentação de Imagens

S.Furuiê /EPUSP-21

Otsu



$$S(C_1, C_2) = \frac{\sigma_b^2(C_1, C_2)}{\sigma_0^2}$$

$$\sigma_0^2 = \sum_{i=0}^{L-1} (i - m_0)^2 \cdot P(i)$$

$$m_0 = \sum_{i=0}^{L-1} i \cdot P(i)$$

$$\sigma_b^2(C_1, C_2) = P_1(m_1 - m_0)^2 + P_2(m_2 - m_0)^2$$

$$m_1 = m_1(T) = \sum_{i=0}^T i \cdot P(i | C_1)$$

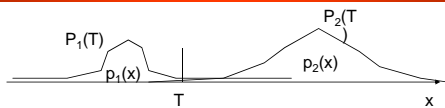
$$m_2 = m_2(T) = \sum_{i=T+1}^{L-1} i \cdot P(i | C_2)$$

$$\Rightarrow \max_T \sigma_b^2(C_1, C_2)$$

Segmentação de Imagens

S.Furuiê /EPUSP-22

Optimal thresholding: Otsu



$$m_1 = \sum_{i=0}^T i \cdot P(i | C_1) = \sum_{i=0}^T i \cdot \frac{P(C_1 | i) \cdot P(i)}{P(C_1)} = \frac{1}{P_1} \sum_{i=0}^T i \cdot P(i) = \frac{m(T)}{P_1}$$

$$m(T) = \sum_{i=0}^T i \cdot P(i)$$

$$m_2 = \sum_{i=T+1}^{L-1} i \cdot P(i | C_2) = \frac{m_0 - m(T)}{P_2}$$

$$\Rightarrow \sigma_b^2(C_1, C_2; T) = \frac{(m_0 P_1(T) - m(T))^2}{P_1(T) \cdot (1 - P_1(T))}$$

Segmentação de Imagens

S.Furuiê /EPUSP-23

Efeito da filtragem

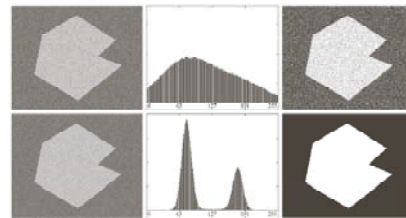


FIGURE 10.40 (a) Noisy image from Fig. 10.36 and (b) its histogram. (c) Result obtained using Otsu's method. (d) Noisy image smoothed using a 5×5 averaging mask and (e) its histogram. (f) Result of thresholding using Otsu's method.

Segmentação de Imagens

S.Furuiê /EPUSP-24

Efeito da falta de bimodalidade

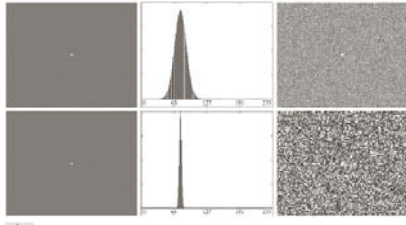


FIGURE 10.41 (a) Noisy image and (b) its histogram. (c) Result obtained using Otsu's method. (d) Noisy image smoothed using a 2×2 averaging mask and (e) its histogram. (f) Result of thresholding using Otsu's method. Thresholding failed in both cases.

Segmentação de Imagens

S.Furuié /EPUSP-25

Histograma focado na região da borda (bimodal)

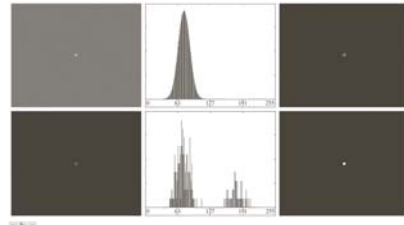


FIGURE 10.42 (a) Noisy image from Fig. 10-11(a) and (b) its histogram. (c) Gradient magnitude image thresholded at the 99.7 percentile. (d) Image focused on the pixels of (c) and (e) Histogram of the nonzero pixels in the image in (d). (f) Result of segmenting image (a) with the Otsu threshold based on the histogram in (e). The threshold was 134, which is approximately midway between the peaks in the histogram.

Segmentação de Imagens

S.Furuié /EPUSP-26

Histograma focado na região da borda (bimodal)

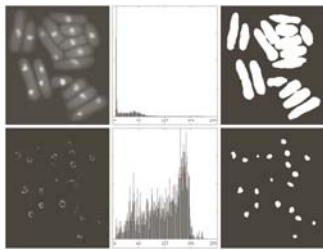


FIGURE 10.43 (a) Image of four fish. (b) Histogram of (a). (c) Segmentation of (a) with Otsu's method using the histogram in (b). (d) Thresholded absolute Laplacian. (e) Histogram of the nonzero pixels in the product of (a) and (d). (f) Output image thresholded using Otsu's method based on the histogram in (e). (Original image courtesy of Professor Juan L. Pineda, University of Indiana-Columbus.)

Segmentação de Imagens

S.Furuié /EPUSP-27

Mais do que 2 classes: generalização da separabilidade

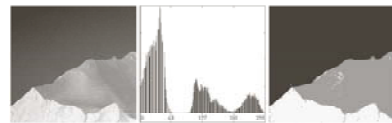


FIGURE 10.45 (a) Image of iceberg. (b) Histogram. (c) Image segmented into three regions using dual Otsu threshold. (Original image courtesy of NOAA.)

Segmentação de Imagens

S.Furuié /EPUSP-28

Otsu em subimagens

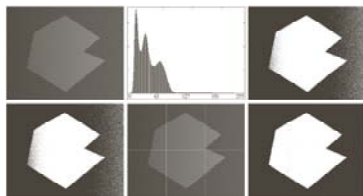


FIGURE 10.46 (a) Noisy, shaded image and (b) its histogram. (c) Segmentation of (a) using the iterative global algorithm from Section 10.3.2. (d) Result obtained using Otsu's method. (e) Image thresholded into six subimages. (f) Result of applying Otsu's method to each subimage individually.

Segmentação de Imagens

S.Furuié /EPUSP-29

Otsu em subimagens

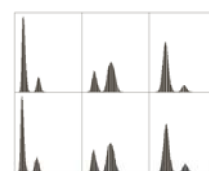


FIGURE 10.47 Histograms of the six subimages in Fig. 10.46(e).

Segmentação de Imagens

S.Furuié /EPUSP-30