

**IA369E**

**Tópicos em Engenharia de Computação VI**  
**Segundo Semestre de 2013**

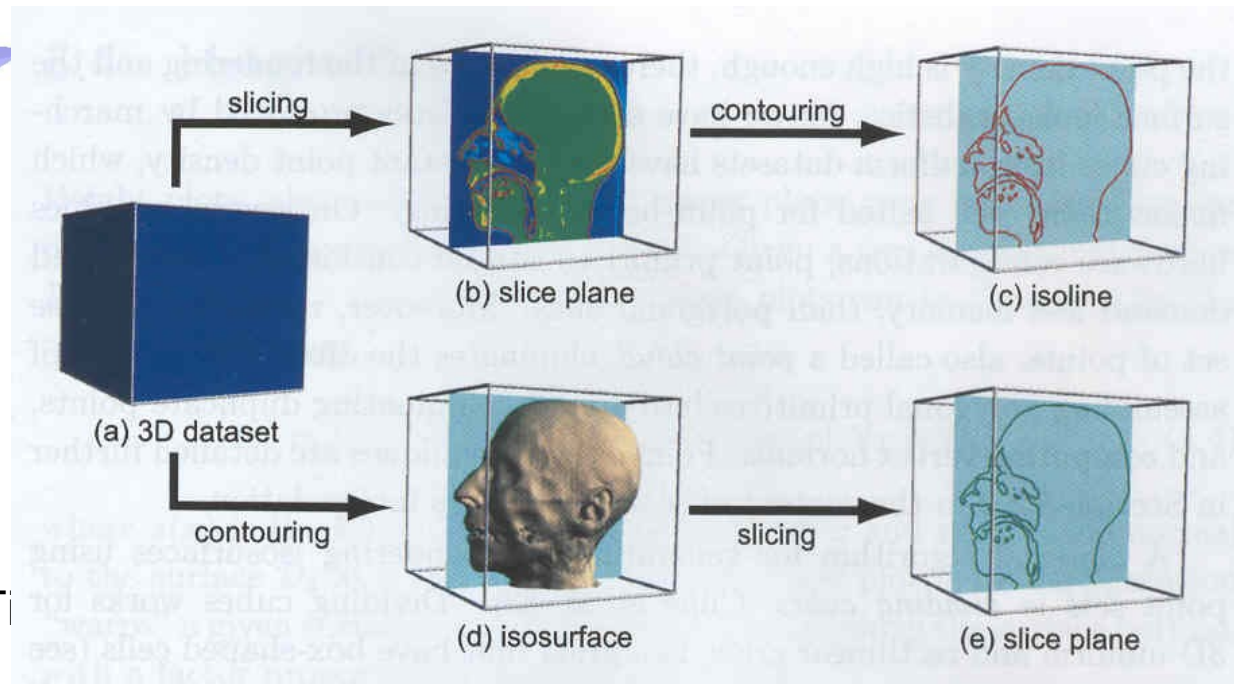
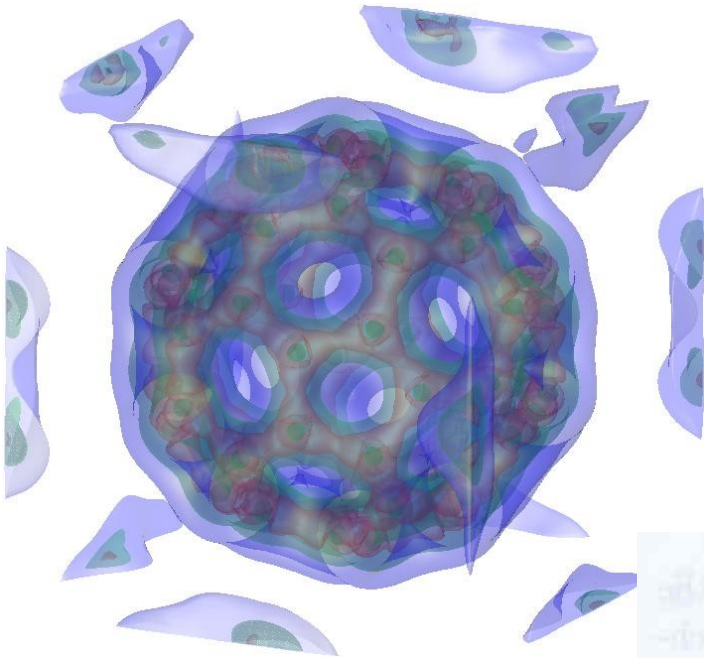
**Visualização de Isosuperfícies**

**Profa. Ting**

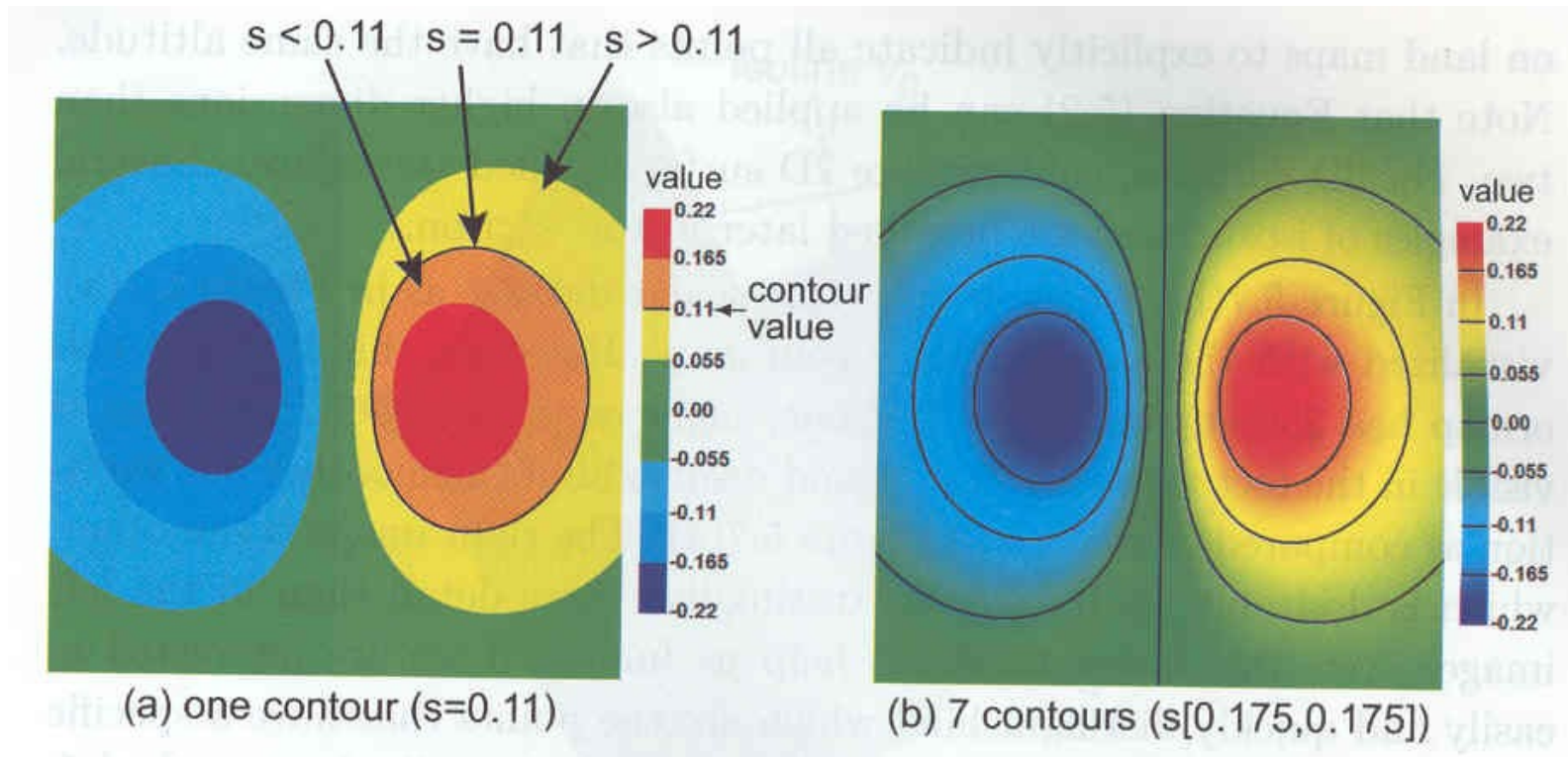
# Isosuperfícies

Conjuntos de *voxels* que apresentam mesmos valores escalares  $c$  (isovlores).

$$f(x, y, z) = c$$

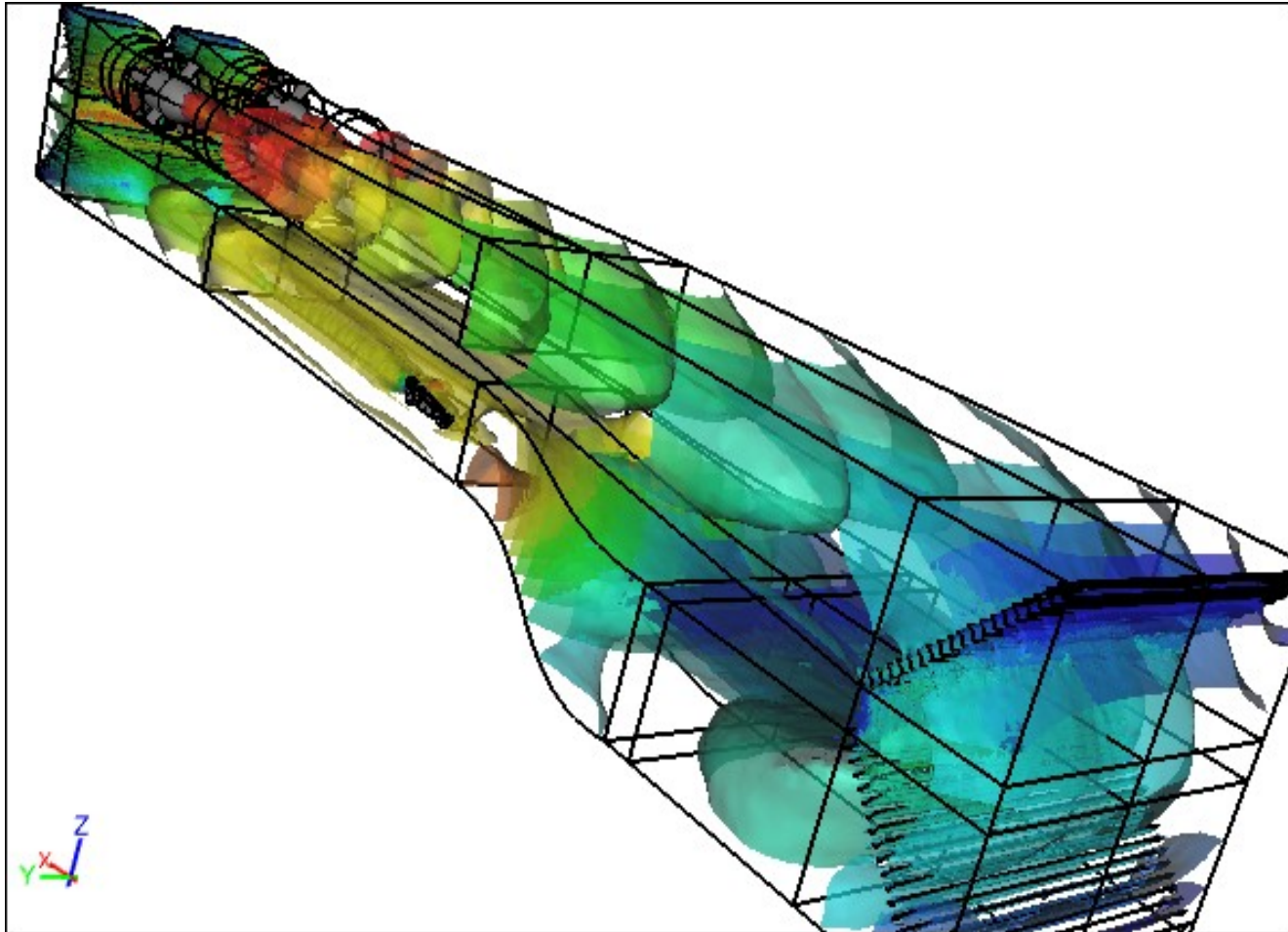


# Representação Gráfica

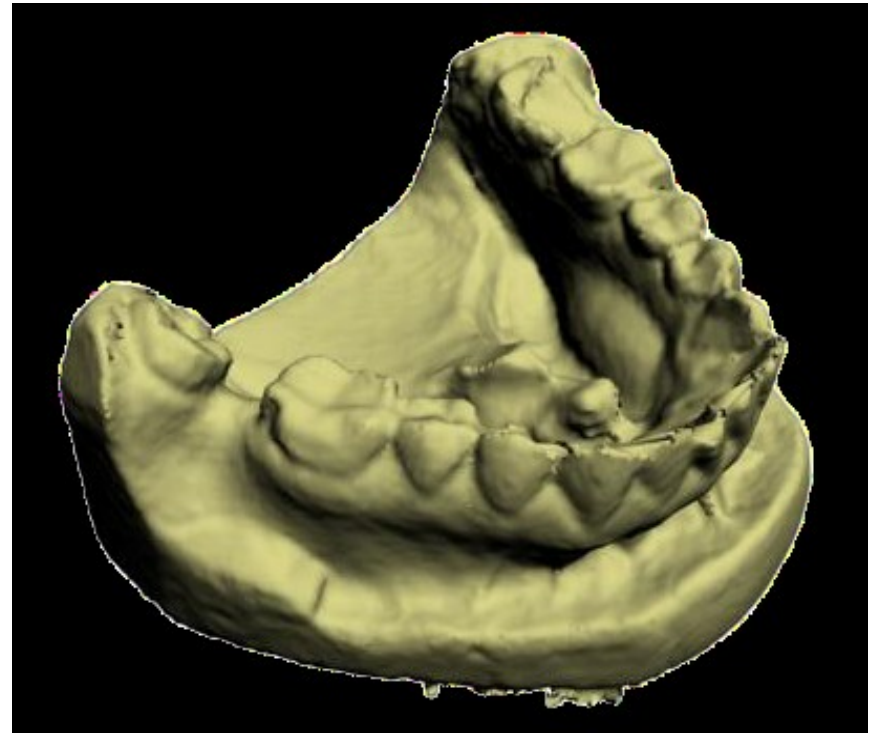
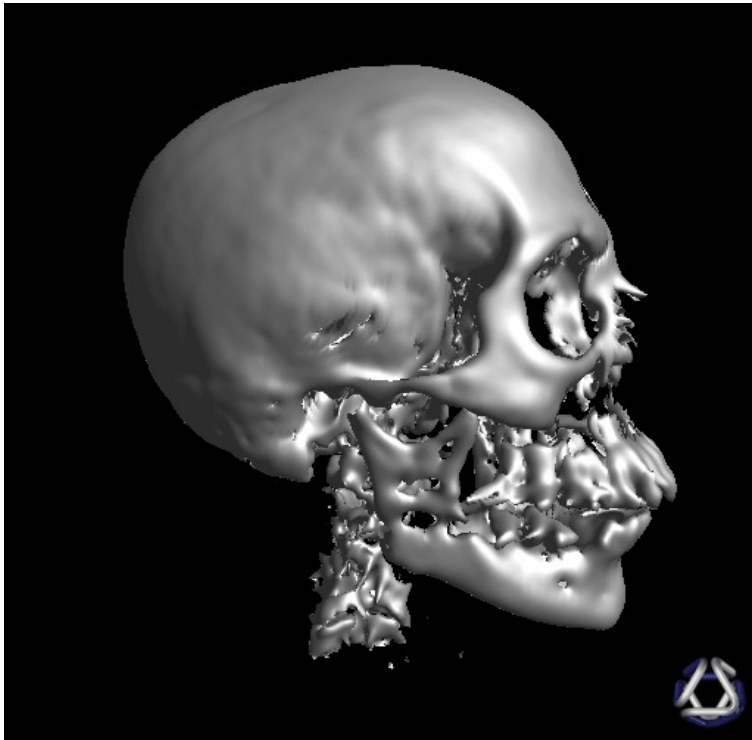


Espaçamento entre curvas indica a velocidade de variação dos valores

# CFD



# Imagens Médicas

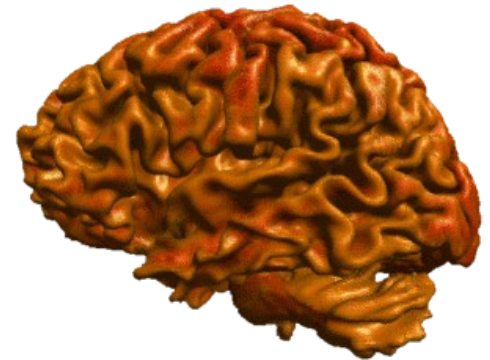
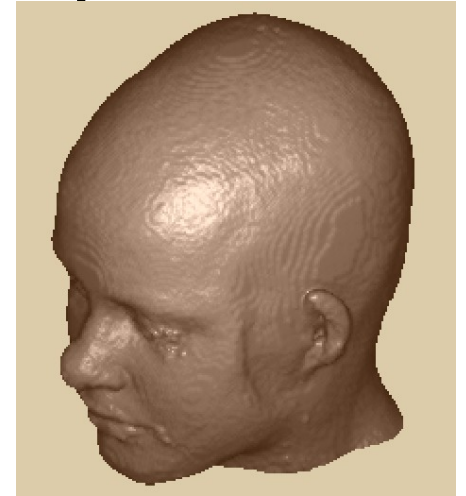
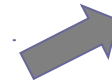
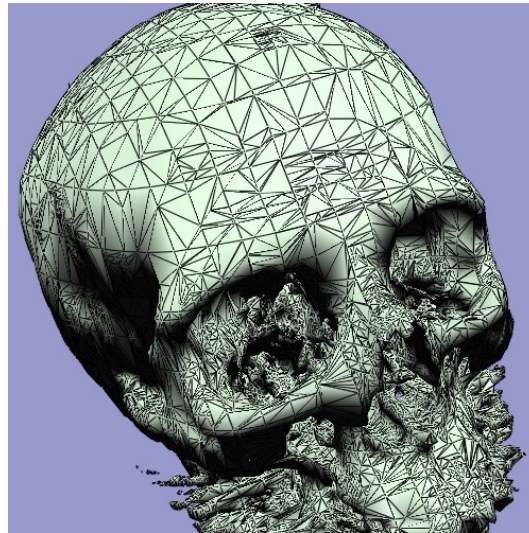
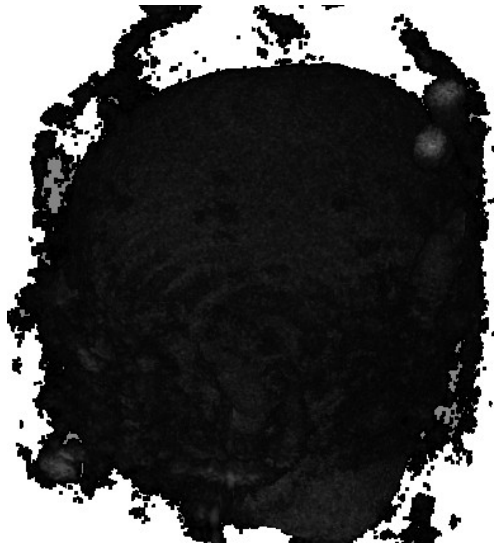


# Técnicas de Renderização

- ISR – renderização de isosuperfície indireta
- DSR – renderização direta de superfície

# ISR

- Renderização Indireta via isosuperfície



Extração de isosuperfície

Fonte: *Google imagel*

# Técnicas de Extração

<http://swiftcoder.wordpress.com/planets/isosurface-extraction/>

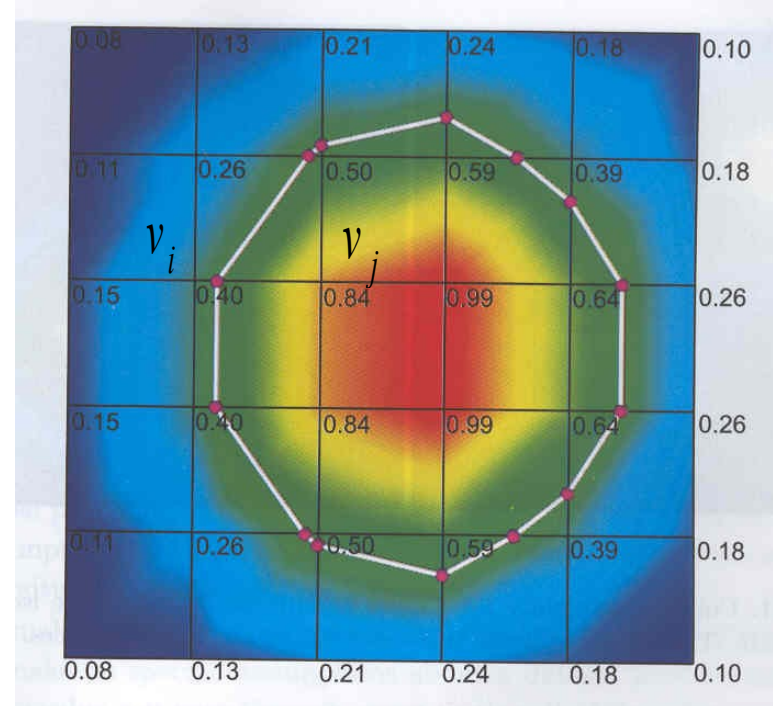


# Extração de Isocurvas

- Como determinar a partir dos valores das amostras conjunto de níveis?
  - Determinar os pontos em cada face da célula
  - Conectar os “pontos” interpolados em cada célula
  - Agrupar os segmentos para formar um conjunto de nível ou utilizar ou renderizar como pontos dispersos

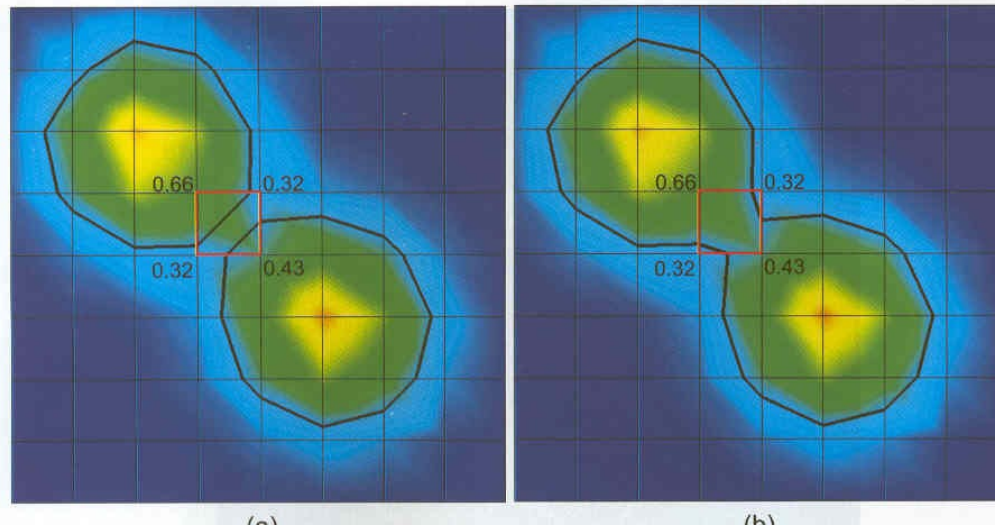
$$v_i < v < v_j$$

$$q = \frac{p_i(v_j - v) + p_j(v - v_i)}{v_j - v_i}$$

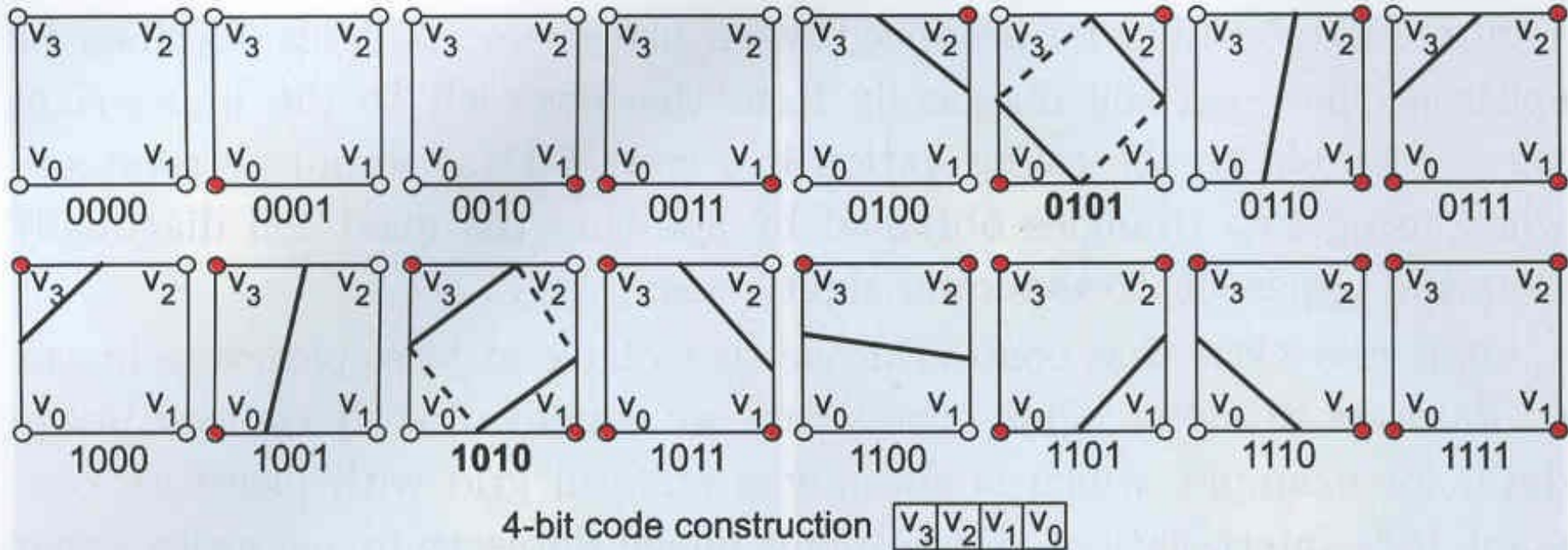


# Ambiguidades

- Como determinar a partir dos valores das amostras conjuntos de nível?
  - Determinar os pontos em cada face da célula
  - Conectar os “pontos” interpolados em cada célula
  - Agrupar os segmentos para formar um conjunto de nível ou renderizar diretamente como pontos dispersos



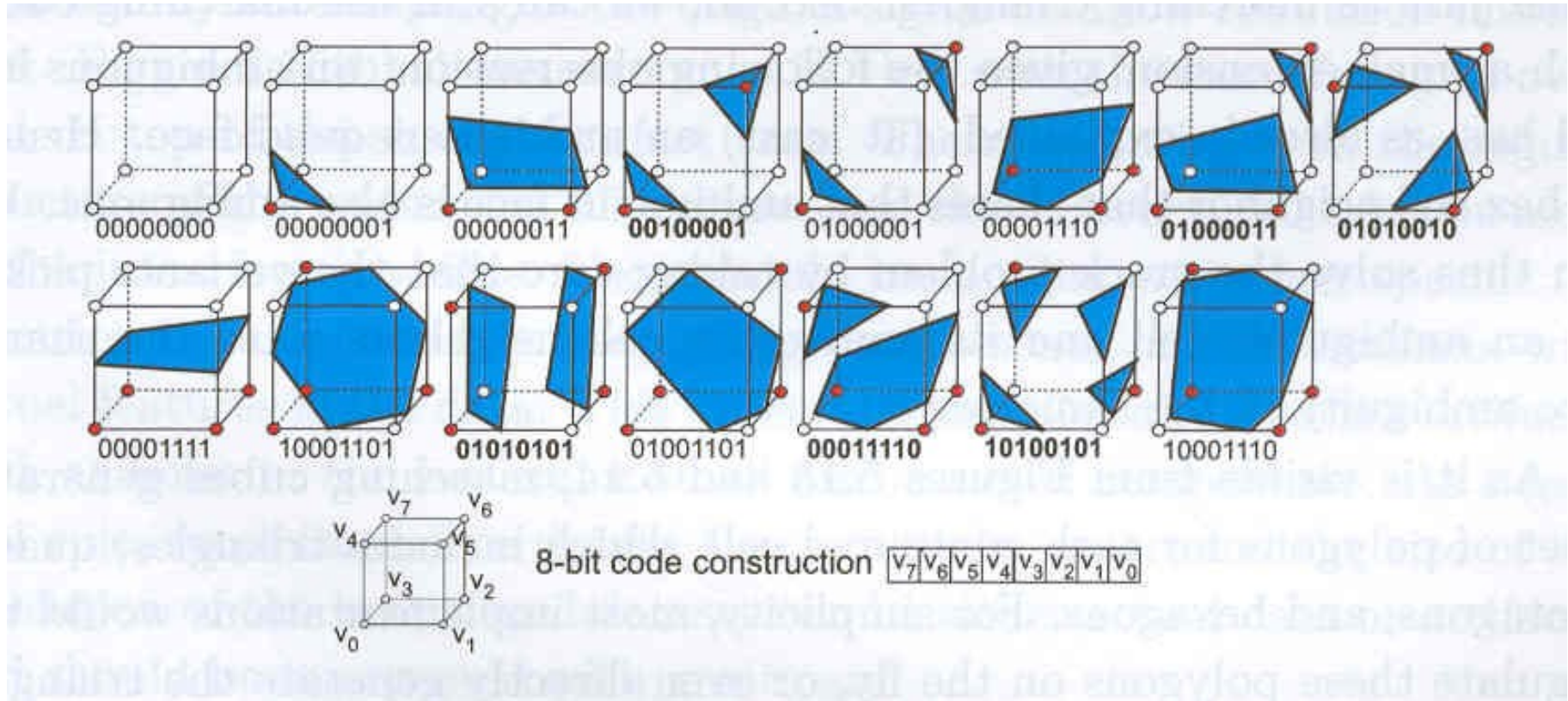
# Algoritmo *Marching Square* 2D



4 vértices  $\rightarrow 2^4$  possibilidades

# Algoritmo *Marching Cube*

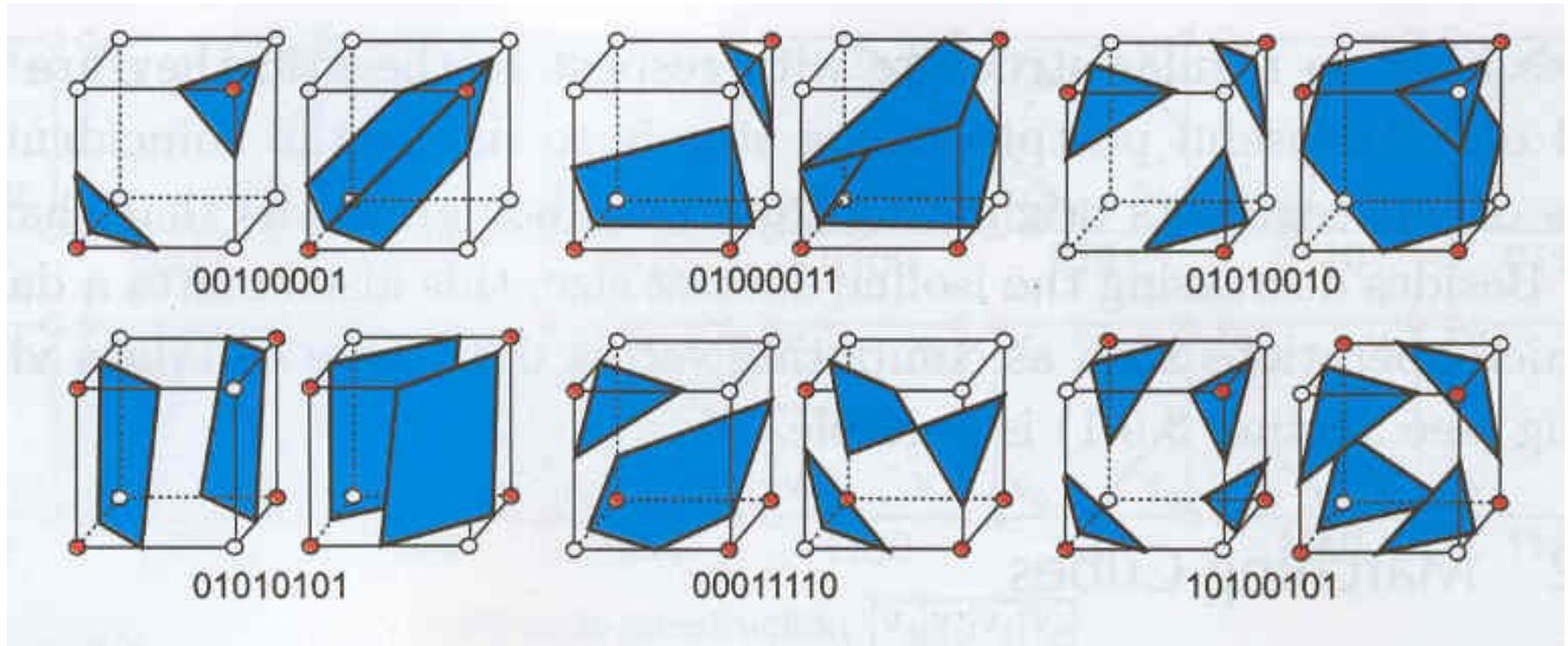
## 3D



8 vértices  $\rightarrow 2^8$  possibilidades  $\rightarrow 15$  casos

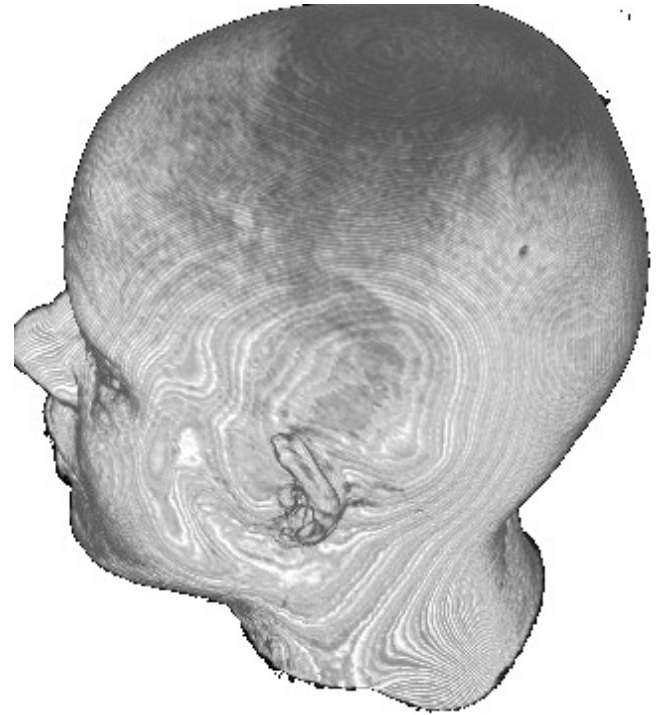
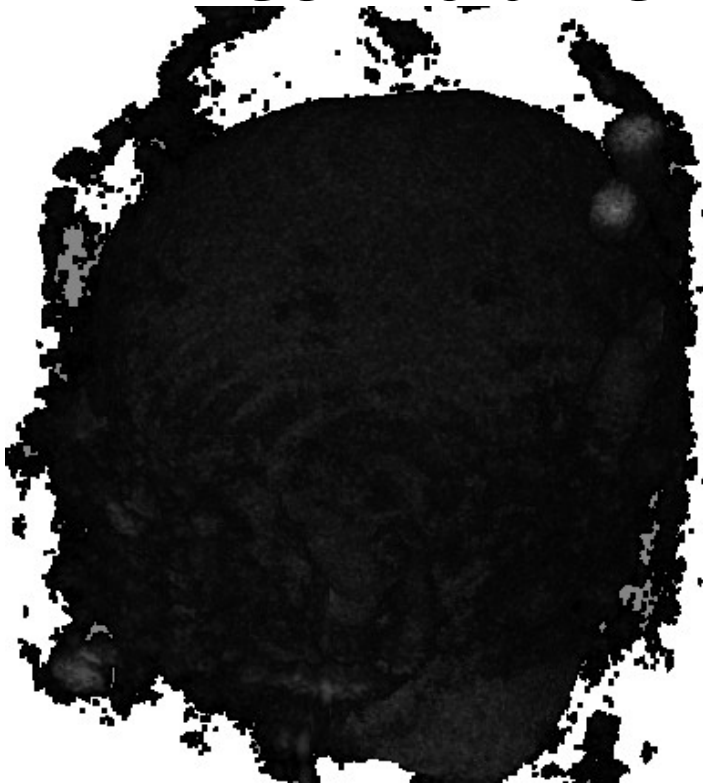
# Algoritmo *Marching Cube*

## Ambiguidades



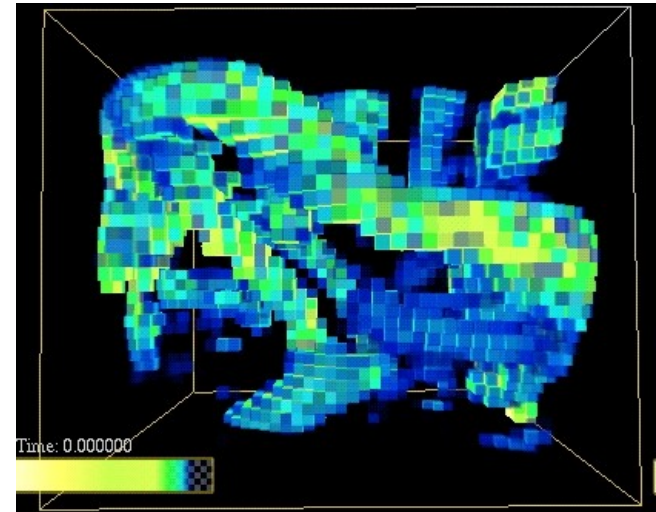
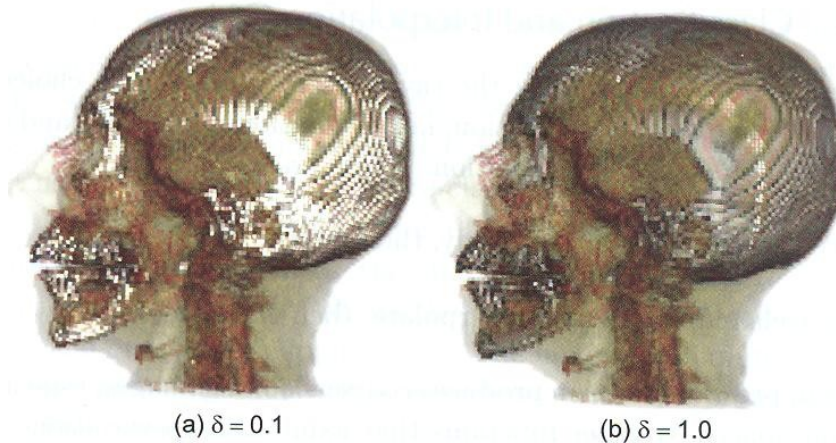
# DSR

- Renderização Direta
  - *Direct Surface Rendering* (DSR)
  - *Direct Volume Rendering* (DVR)

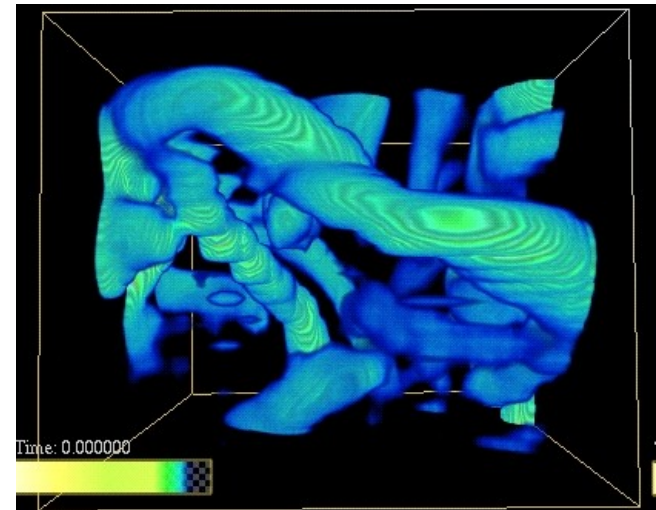
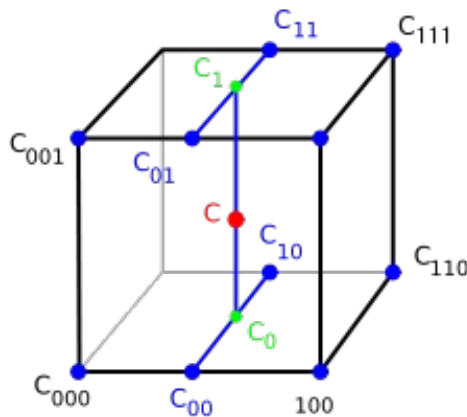


# Técnicas de Interpolação

- Vizinho-mais-próximo

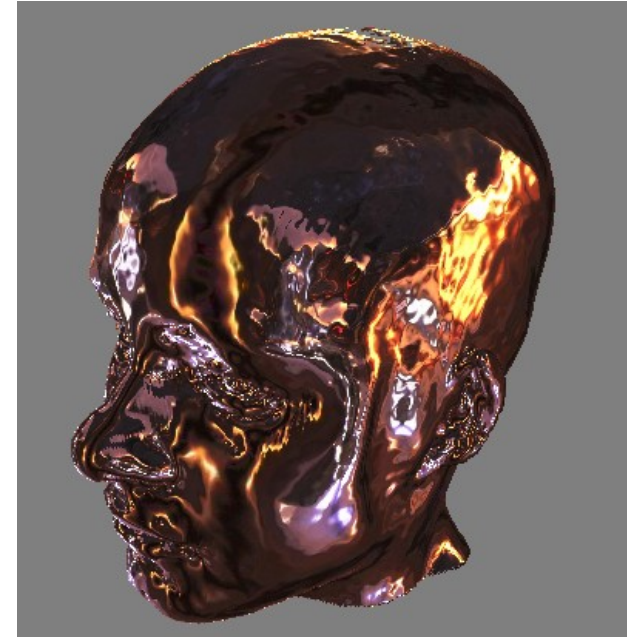
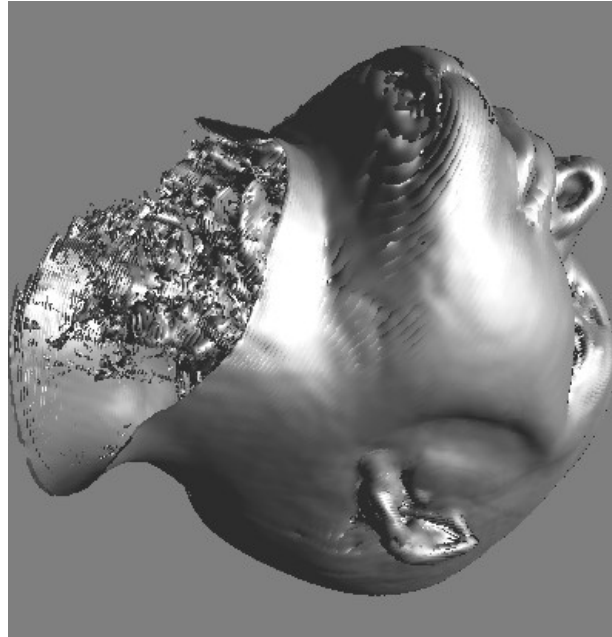


- Interpolação trilinear



# Ray-Casting + Modelo de Iluminação

- Modelo de iluminação clássica em amostras visíveis
  - Gradientes das intensidades  $\rightarrow$  vetor

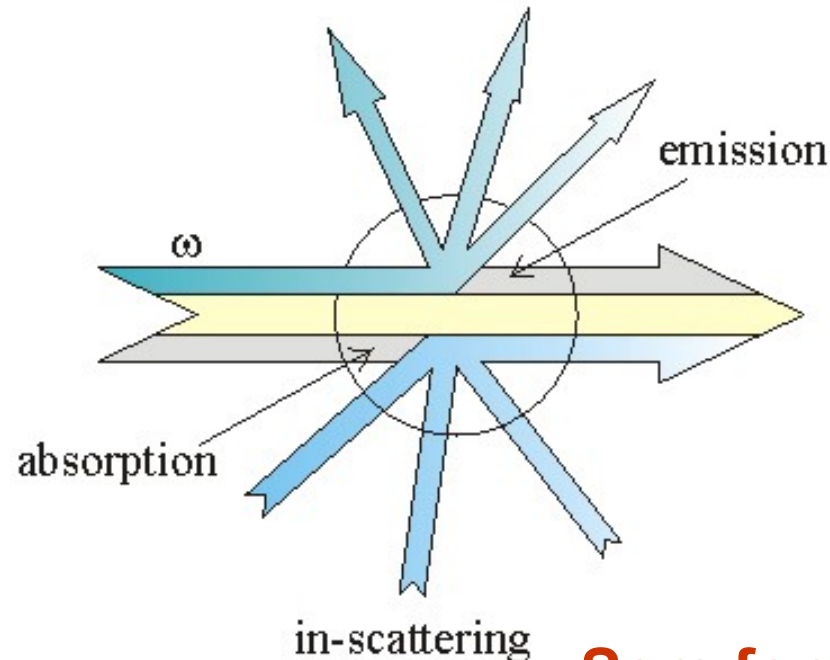




# Equação de *Rendering* Volumétrica

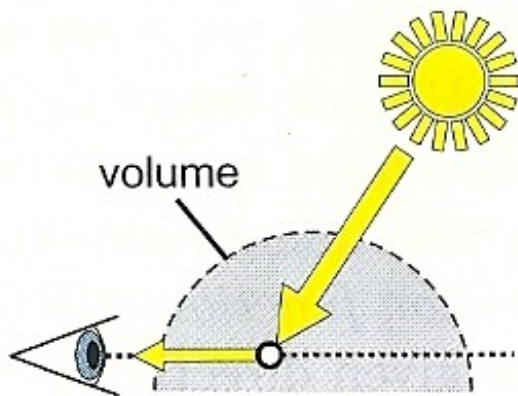
## Modelo Absorção-Emissão

$$I(D) = I_0 e^{-\int_{s_0}^D \kappa(t) dt} + \int_{s_0}^D q(s) e^{-\int_s^D \kappa(t) dt} ds$$

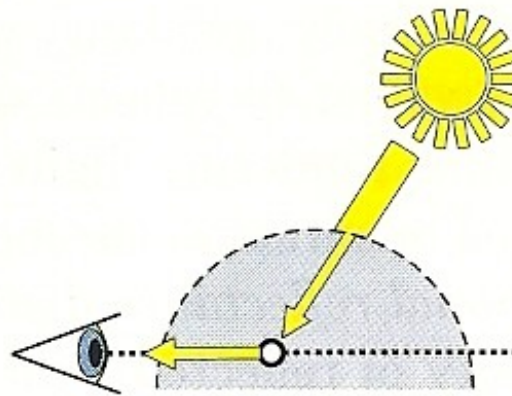


**Sem fonte de luz externa!**

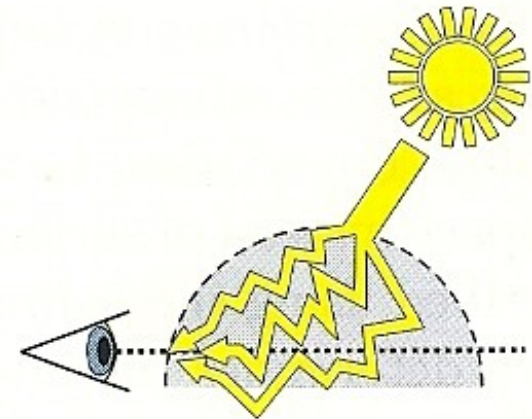
# Reflexões e Refrações



simples



simples  
com  
atenuações



difusas/  
múltiplas

**Iluminação Local**

**Iluminação Global**

# Modelos de Iluminação Local aplicados em superfícies

- Phong
- Blinn-Phong
- Cook-Torrance

Lafortune's model

Banks' anisotropic model

Ashikhmin's model

etc.

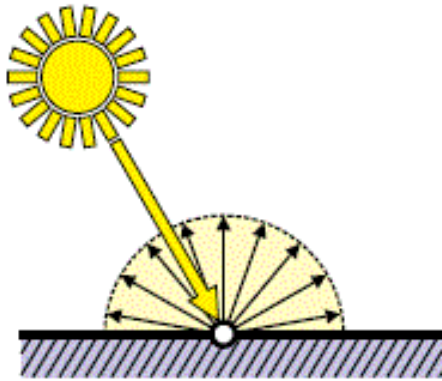
} Paradigma orientado à “lógica do fenômeno”

} Paradigma orientado à “física do fenômeno”

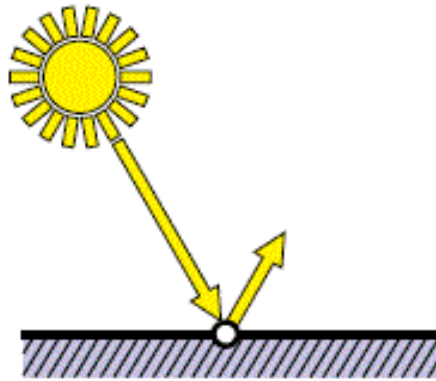
# Modelo de Iluminação Phong

$$I_{Phong} = I_{ambiente} + I_{difuso} + I_{especular}$$

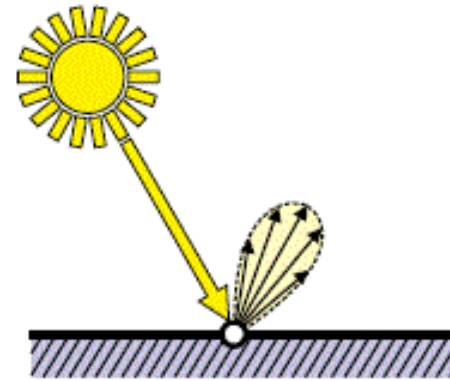
Multi-reflexões → *fill lights*



**Reflexões difusas**  
(Superfície lambertiana)

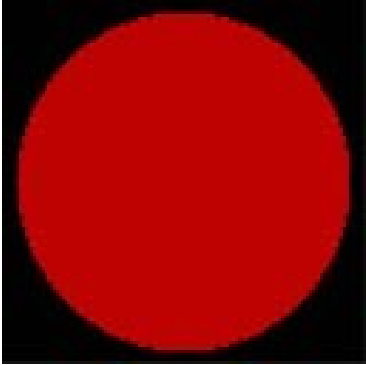


**Reflexões  
espelhadas**



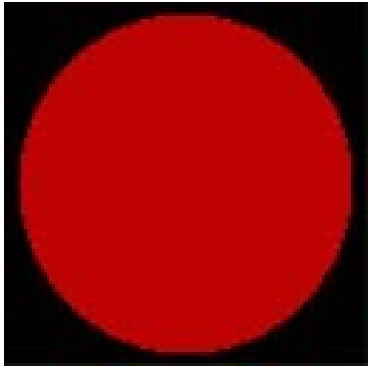
**Reflexões  
especulares**

# Modelo de Iluminação Phong

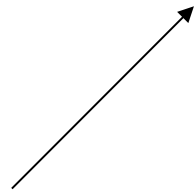
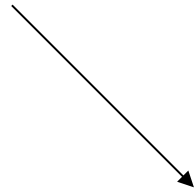


ambiente

# Modelo de Iluminação Phong

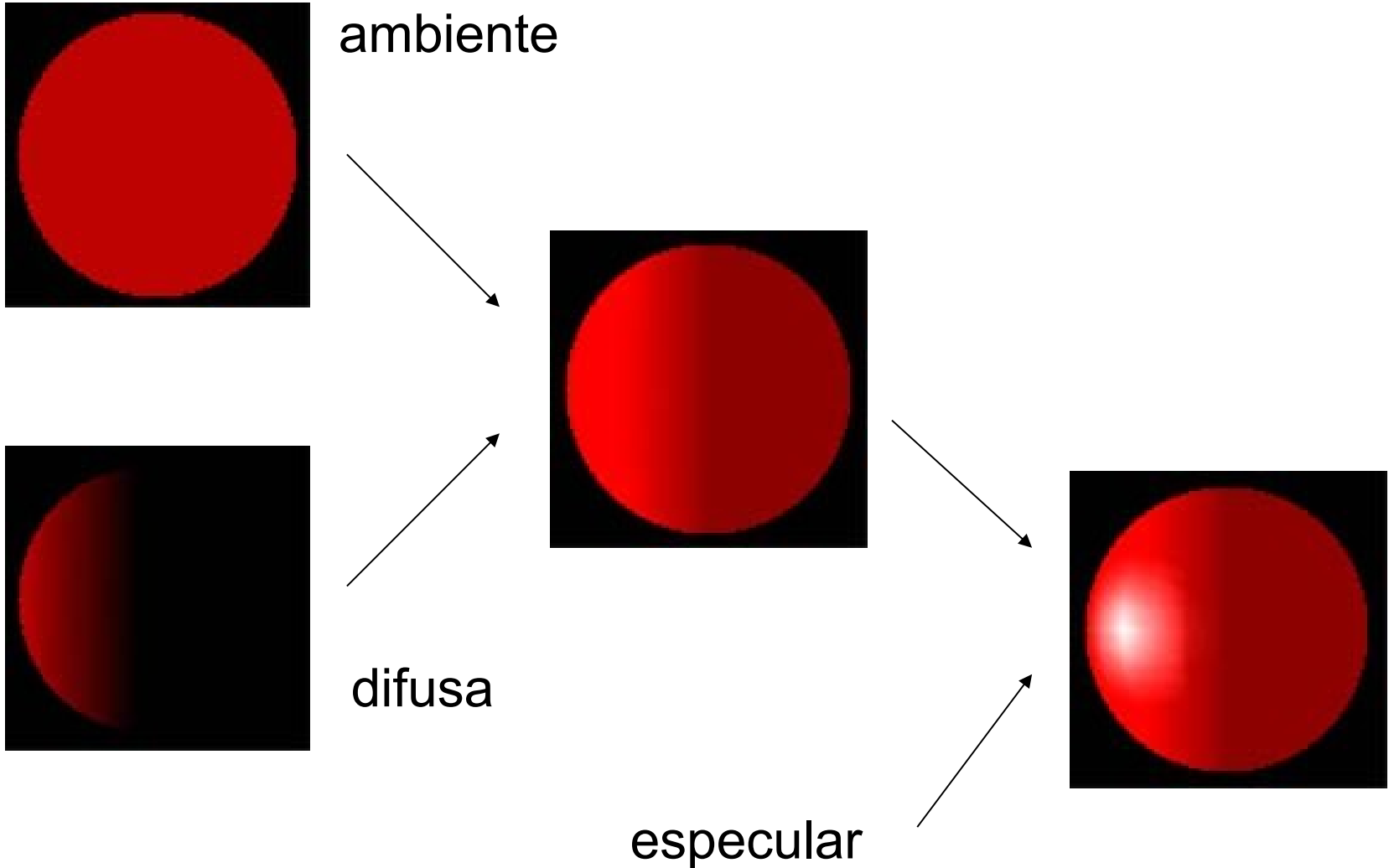


ambiente



difusa

# Modelo de Iluminação Phong



# Modelo de Iluminação Phong

$$I_{Phong} = I_{ambiente} + I_{difuso} + I_{especular}$$

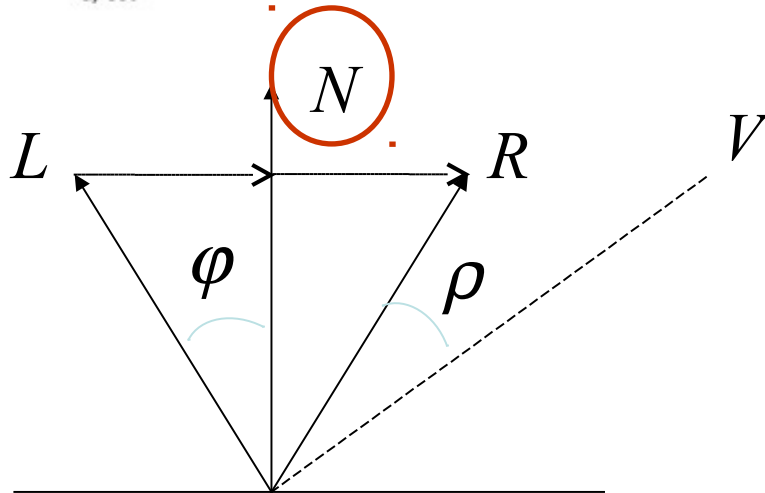
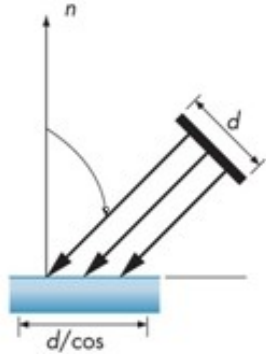
$$= k_a M_a I_a + k_d M_d I_d \cos \phi + k_s M_s I_s \cos^{\alpha} \rho$$

$$k_a + k_d + k_s \leq 1.0$$

$$\cos \phi = \frac{\vec{N} \cdot \vec{L}}{|\vec{N}| |\vec{L}|}$$

$$\cos \rho = \frac{\vec{R} \cdot \vec{V}}{|\vec{R}| |\vec{V}|}$$

$$R = 2N(N \cdot L) - L$$

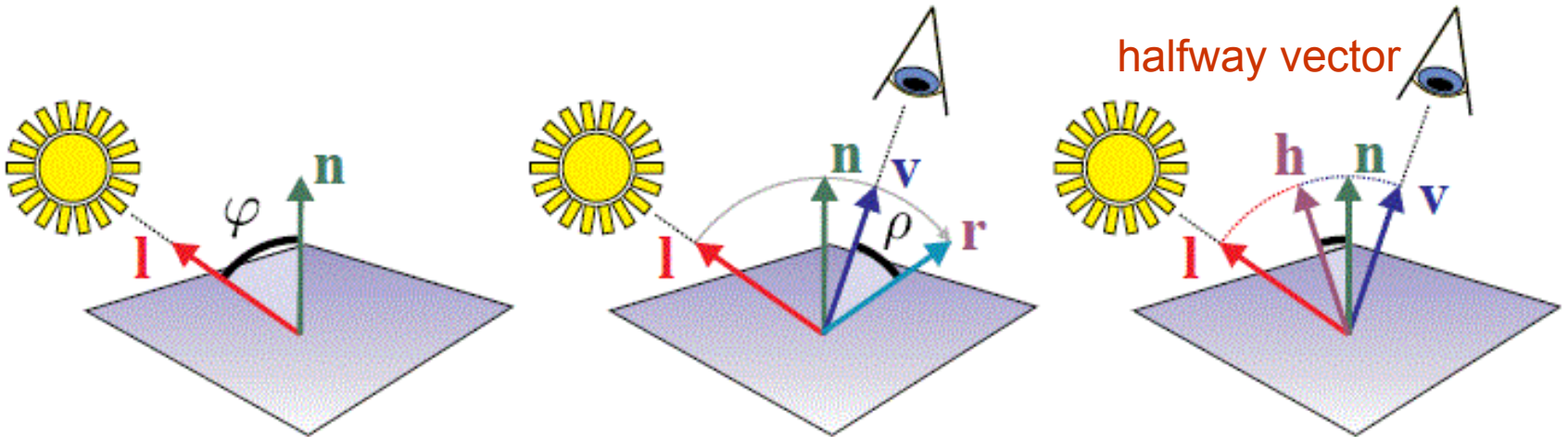




# Modelo de Iluminação Blinn-Phong

$$I_{\text{Blinn-Phong}} = I_{\text{ambiente}} + I_{\text{difuso}} + I_{\text{especular}}$$

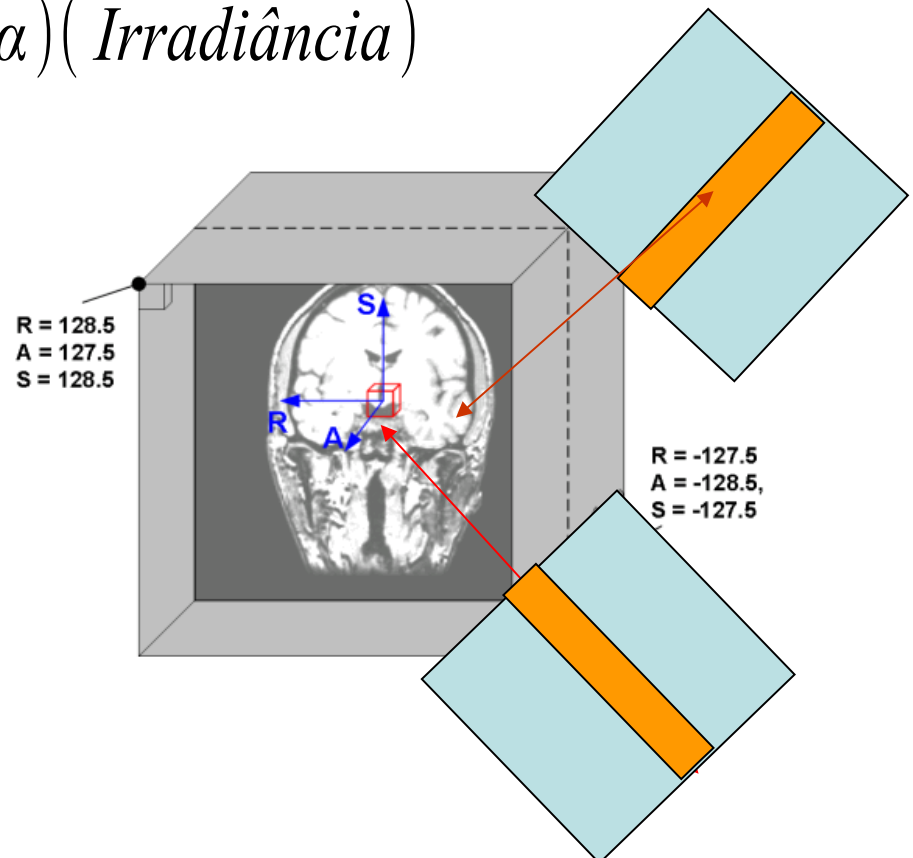
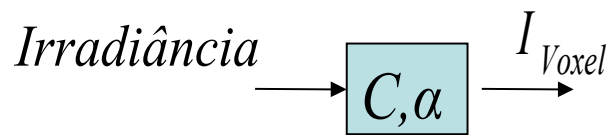
$$= k_a M_a I_a + k_d M_d I_d \cos \phi + k_s M_s I_s \left( \frac{\vec{H} \cdot \vec{N}}{|\vec{H}| |\vec{N}|} \right)^\alpha$$



$$\vec{H} = \frac{\vec{V} + \vec{L}}{|\vec{V} + \vec{L}|}$$

# Modelos de Iluminação Local aplicados em dados voluméricos

$$I_{Volume} = I_{emissão} + \underbrace{(I_{ambiente} + I_{difuso} + I_{especular})}_{(1-\alpha)(Irradiância)}$$



# Modelos de Iluminação Local aplicados em dados volumétricos

$$I_{Volume} = I_{emissão} + (I_{ambiente} + I_{difuso} + I_{especular})$$

$$= k_e I_e + k_a M_a I_a + k_d M_d I_d (\vec{L} \cdot \vec{N}) + k_s M_s I_s (\vec{H} \cdot \vec{N})^\alpha$$

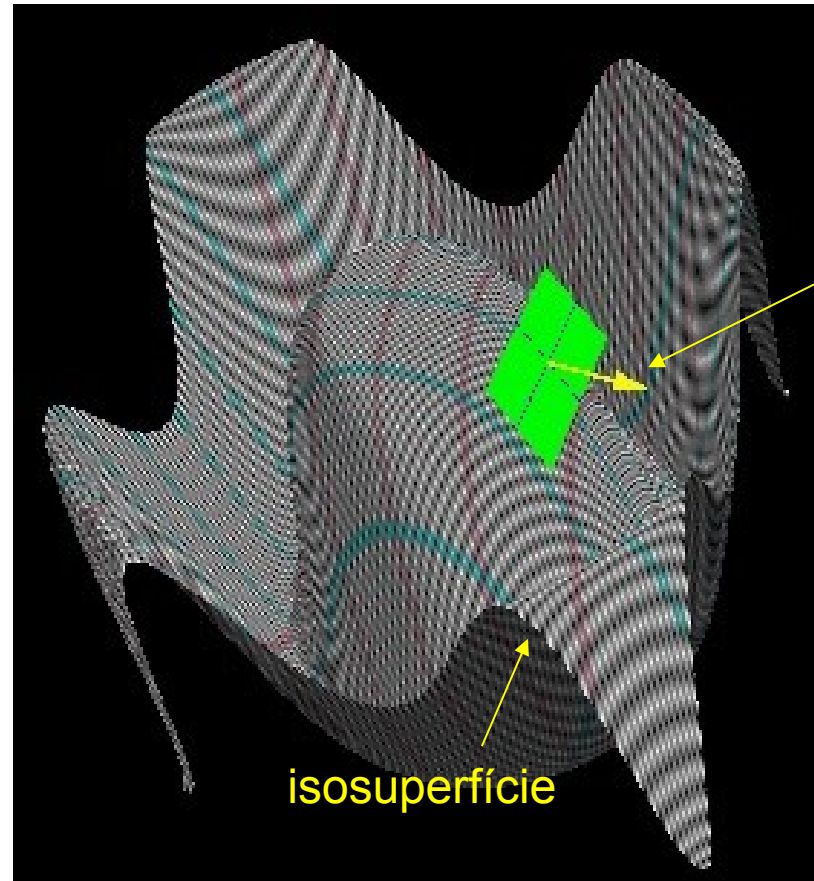
**Função de Transferência**

$$I_e = T(s(x))$$

**Paradigma Clássico  
ou**

**Funções de Transferência**

# Estimativa de Vetores Normais



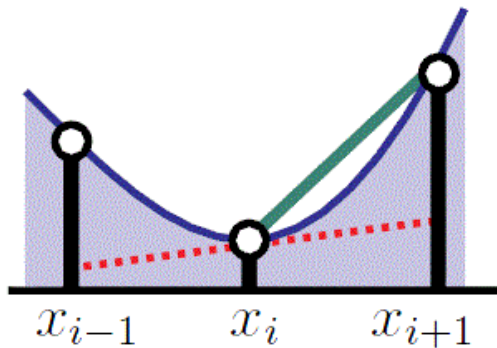
$$\nabla f(x,y,z) = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \\ \frac{\partial f}{\partial z} \end{bmatrix}$$

$$\vec{n} = \frac{\nabla f(x,y,z)}{\|\nabla f(x,y,z)\|}$$

$$\|\nabla f(x,y,z)\| \neq 0$$

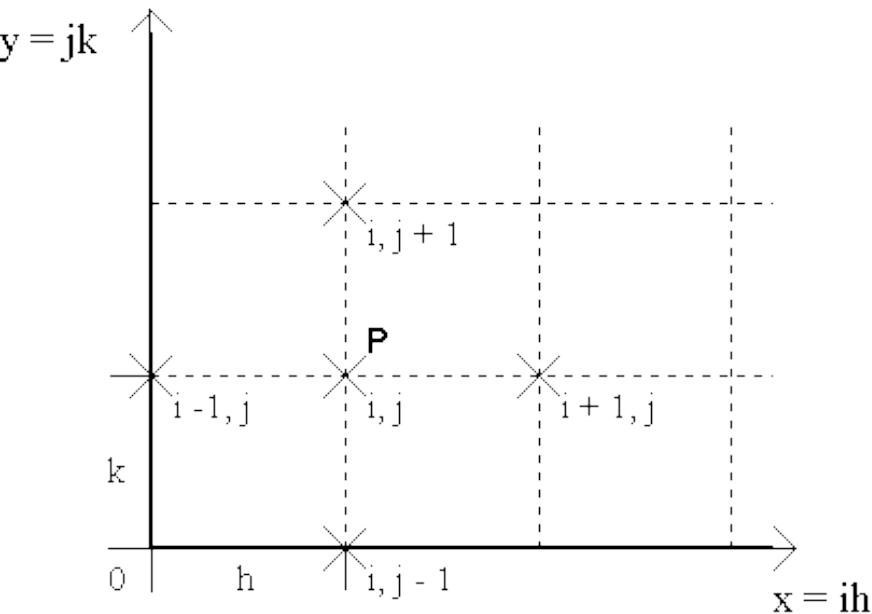
# Aproximação por Série de Taylor

## Diferença Finita Ascendente



$$f(P+h) = f(P) + \frac{f'(P)}{1!}h + \frac{f''(P)}{2!}h^2 + \dots$$

$$= \sum_{n=0}^{\infty} \frac{f^{(n)}(P)}{n!}h^n$$



Isolando o termo de primeira derivada:

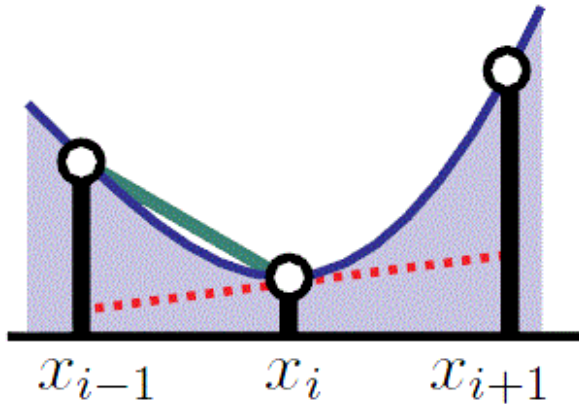
$$\frac{f'(P)}{1!}h = f(P+h) - f(P) - \varepsilon(h^2)$$

$$f'(P) = \frac{f(P+h) - f(P)}{h} + \frac{-\varepsilon(h^2)}{h}$$

$$= \frac{f(P+h) - f(P)}{h} + o(h)$$

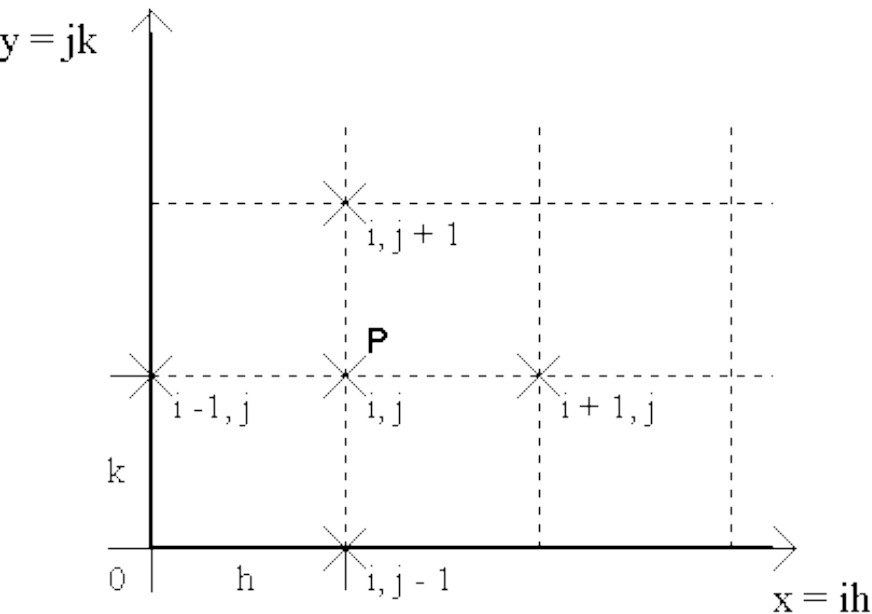
# Aproximação por Série de Taylor

## Diferença Finita Descendente



$$f(P-h) = f(P) - \frac{f'(P)}{1!}h + \frac{f''(P)}{2!}h^2 - \dots$$

$$= \sum_{n=0}^{\infty} \frac{(-1)^n f^n(P)}{n!} h^n$$



Isolando o termo de primeira derivada:

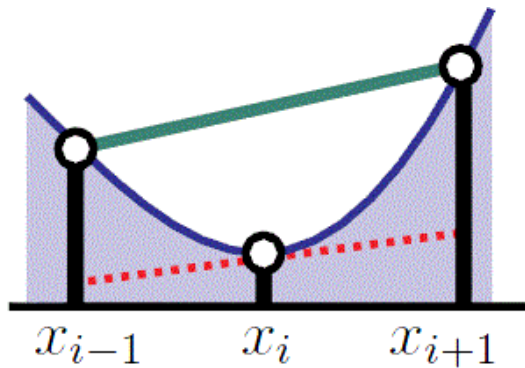
$$\frac{f'(P)}{1!}h = f(P) - f(P-h) + \varepsilon(h^2)$$

$$f'(P) = \frac{f(P) - f(P-h)}{h} + \frac{\varepsilon(h^2)}{h}$$

$$= \frac{f(P) - f(P-h)}{h} + o(h)$$

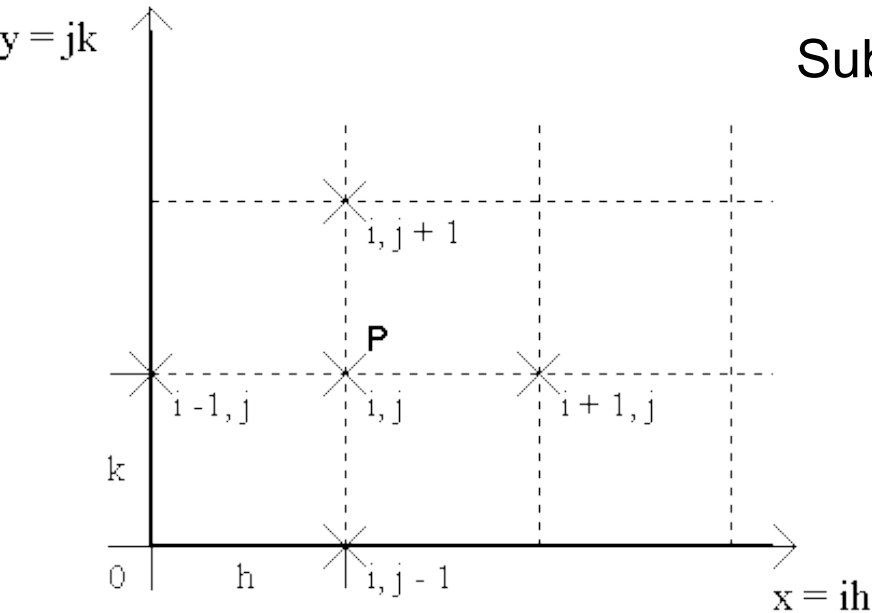
# Aproximação por Série de Taylor

## Diferença Finita Central



$$f(P+h) = f(P) + \frac{f'(P)}{1!}h + \frac{f''(P)}{2!}h^2 + \frac{f'''(P)}{3!}h^3 \dots$$

$$f(P-h) = f(P) - \frac{f'(P)}{1!}h + \frac{f''(P)}{2!}h^2 - \frac{f'''(P)}{3!}h^3 \dots$$



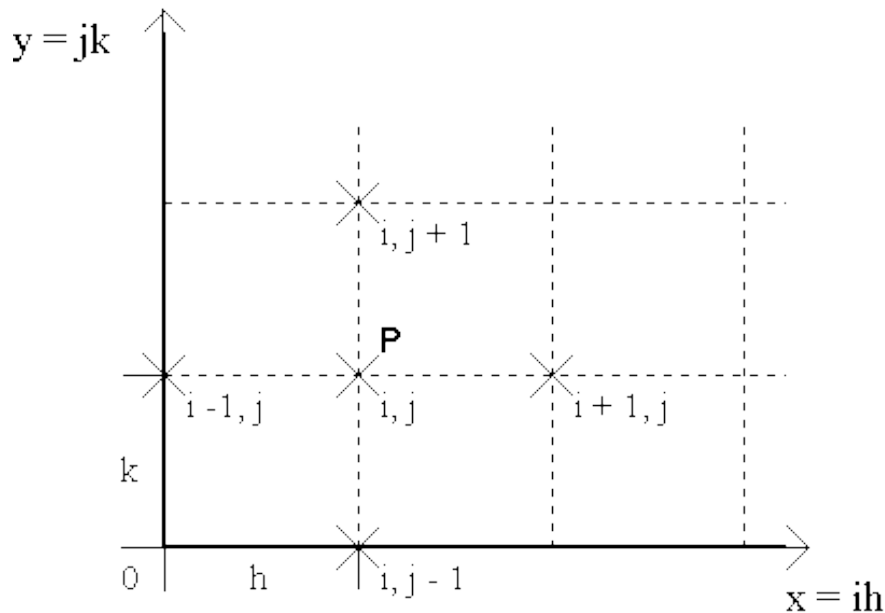
Subtraindo a segunda expressão da primeira:

$$2f'(P)h = f(P+h) - f(P-h) + \varepsilon(h^3)$$

$$f'(P) = \frac{f(P+h) - f(P-h)}{2h} + \frac{\varepsilon(h^3)}{2h}$$

$$= \frac{f(P+h) - f(P-h)}{2h} + o(h^2)$$

# Aproximação por Diferenças Finitas



Diferença finita central:

$$\left(\frac{\partial u}{\partial x}\right)_P = \left(\frac{\partial u}{\partial x}\right)_{i,j} \approx \frac{u_{i+1,j} - u_{i-1,j}}{2h}$$

$$\left(\frac{\partial u}{\partial y}\right)_P = \left(\frac{\partial u}{\partial y}\right)_{i,j} \approx \frac{u_{i,j+1} - u_{i,j-1}}{2k}$$

Diferença finita ascendente:

$$\left(\frac{\partial u}{\partial x}\right)_P = \left(\frac{\partial u}{\partial x}\right)_{i,j} \approx \frac{u_{i+1,j} - u_{i,j}}{h}$$

$$\left(\frac{\partial u}{\partial y}\right)_P = \left(\frac{\partial u}{\partial y}\right)_{i,j} \approx \frac{u_{i,j+1} - u_{i,j}}{k}$$

Diferença finita descendente:

$$\left(\frac{\partial u}{\partial x}\right)_P = \left(\frac{\partial u}{\partial x}\right)_{i,j} \approx \frac{u_{i,j} - u_{i-1,j}}{h}$$

$$\left(\frac{\partial u}{\partial y}\right)_P = \left(\frac{\partial u}{\partial y}\right)_{i,j} \approx \frac{u_{i,j} - u_{i,j-1}}{k}$$



# Uma Implementação

$$\nabla f(x,y,z) = \frac{1}{2h} \begin{bmatrix} f(x+h,y,z) - f(x-h,y,z) \\ f(x,y+h,z) - f(x,y-h,z) \\ f(x,y,z+h) - f(x,y,z-h) \end{bmatrix}$$



Derivar na direção z (Derivar na direção y (Derivar na direção x(P)))

Notação Matricial



$$\begin{bmatrix} (x-h,y-h,z) & (x,y-h,z) & (x+h,y-h,z) \\ (x-h,y,z) & (x,y,z) & (x+h,y,z) \\ (x-h,y+h,z) & (x,y+h,z) & (x+h,y+h,z) \end{bmatrix}$$

$$\begin{bmatrix} (x-h,y-h,z-h) & (x,y-h,z-h) & (x+h,y-h,z-h) \\ (x-h,y,z-h) & (x,y,z-h) & (x+h,y,z-h) \\ (x-h,y+h,z-h) & (x,y+h,z-h) & (x+h,y+h,z-h) \end{bmatrix}$$



# Média Ponderada dos Gradientes

- Objetivo: remover *outliers* ponderando as amostras com pesos distintos
- Ferramenta: Operador de *Sobel*

– 2D

$$\begin{bmatrix} +1 & 0 & -1 \\ +2 & 0 & -2 \\ +1 & 0 & -1 \end{bmatrix} = \begin{bmatrix} 1 \\ 2 \\ 1 \end{bmatrix} \begin{bmatrix} +1 & 0 & -1 \end{bmatrix} \quad \begin{bmatrix} +1 & +2 & +1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} = \begin{bmatrix} +1 \\ 0 \\ -1 \end{bmatrix} \begin{bmatrix} 1 & 2 & 1 \end{bmatrix}$$

*smoothing*      *diferença central*      *diferença central*      *smoothing*  
*h(y)*      *h'(x)*      *h'(y)*      *h(x)*

$$\mathbf{G}_x = \begin{bmatrix} 1 \\ 2 \\ 1 \end{bmatrix} * \left( \begin{bmatrix} +1 & 0 & -1 \end{bmatrix} * \mathbf{A} \right) \quad \text{and} \quad \mathbf{G}_y = \begin{bmatrix} +1 \\ 0 \\ -1 \end{bmatrix} * \left( \begin{bmatrix} 1 & 2 & 1 \end{bmatrix} * \mathbf{A} \right)$$

*Isosuperfície*  
*Convolução*

$$G = \sqrt{G_x^2 + G_y^2}$$

$$\theta = \text{arctg} \left( \frac{G_y}{G_x} \right)$$

# Operador de Sobel 3D

$$h'_x(x,y,z) = h'(x)h(y)h(z)$$

$$\begin{matrix} \boxed{h'_z(:,:,1)} \\ h'_z(:,:,0) \\ \boxed{h'_z(:,:, -1)} \end{matrix} = \begin{matrix} \boxed{1} \\ 2 \\ \boxed{1} \end{matrix} \begin{bmatrix} 1 \\ 2 \\ 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & -1 \end{bmatrix}$$

diferença central na direção x

$$h'_z(:,:, -1) = \begin{bmatrix} +1 & +2 & +1 \\ +2 & +4 & +2 \\ +1 & +2 & +1 \end{bmatrix} \quad h'_z(:,:, 0) = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \quad h'_z(:,:, 1) = \begin{bmatrix} -1 & -2 & -1 \\ -2 & -4 & -2 \\ -1 & -2 & -1 \end{bmatrix}$$

# Gradientes Pré-Computados

- Pré-processamento: para cada *voxel*

$$\nabla f(x,y,z) = \begin{bmatrix} f_x \\ f_y \\ f_z \\ \|\nabla f(x,y,z)\| \end{bmatrix} \rightarrow \begin{bmatrix} \frac{f_{x+1}}{2} \\ \frac{f_{y+1}}{2} \\ \frac{f_{z+1}}{2} \\ \text{valor} \end{bmatrix} \left. \vphantom{\begin{bmatrix} f_x \\ f_y \\ f_z \\ \|\nabla f(x,y,z)\| \end{bmatrix}} \right\} [-1,1]$$

- Em tempo de execução

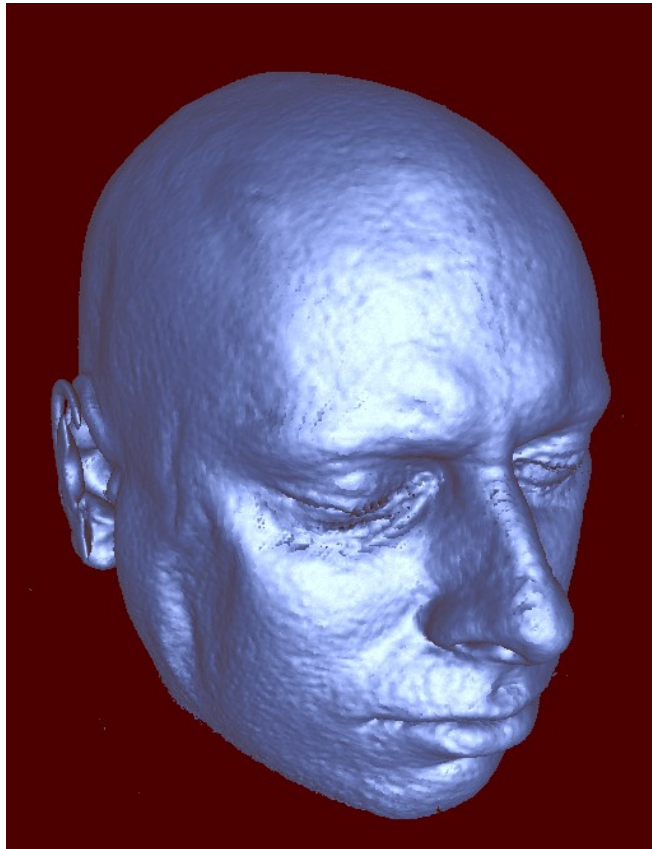
Para cada amostra:

Busca de 6 amostras vizinhas

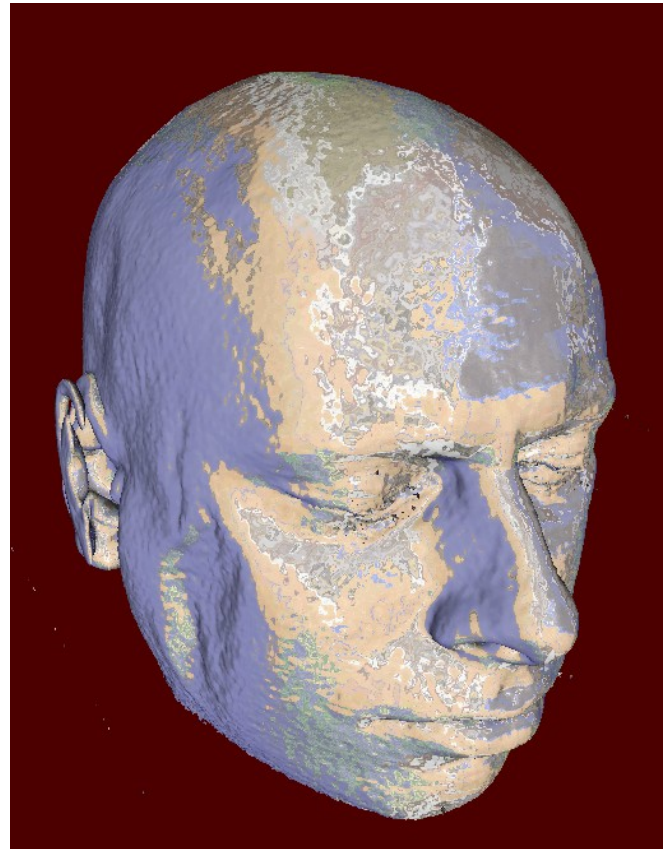


Cômputo de gradiente

# DSR



Com componente especular



Com textura

# Artefatos

- É uma re-amostragem, após uma reconstrução linear → percepção de artefatos em baixa resolução → interpretação equivocada dos dados originais.

