

IA725 – Computação Gráfica I

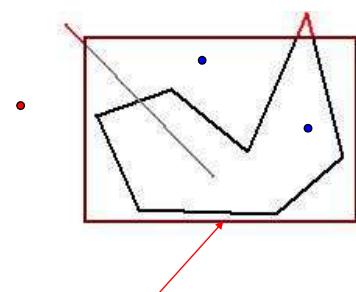
Fluxo Gráfico - Imageamento

Watt: Capítulo 9

Redbook: Capítulo 9

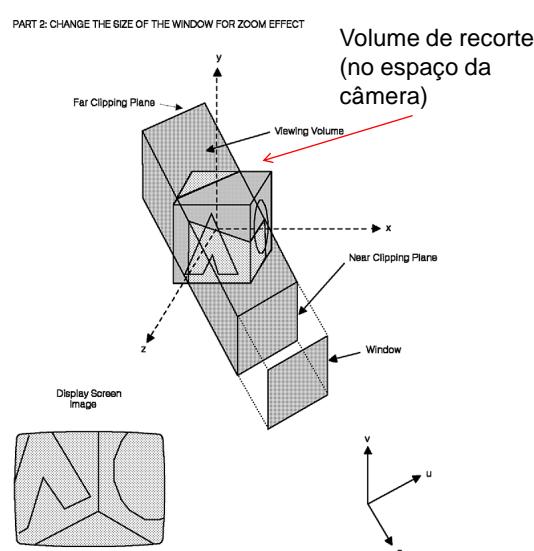
Recorte (*Clipping*)

Partição em dois subespaços: interior e exterior.



Caixa de recorte (no espaço de imagem)

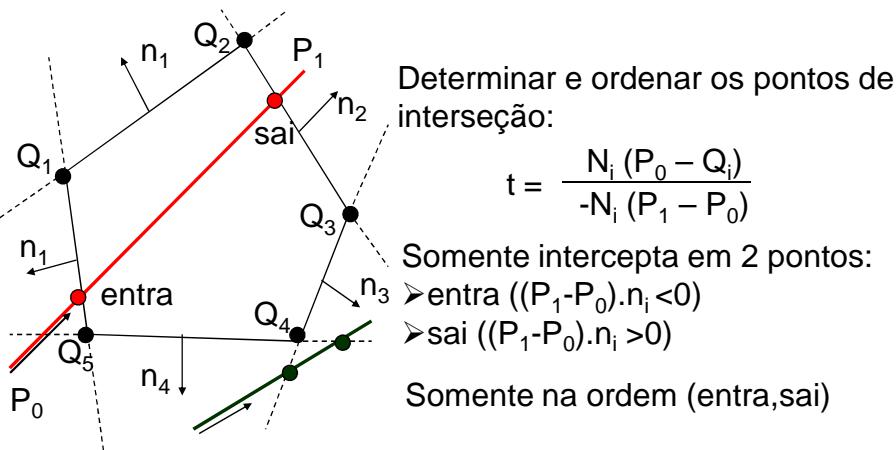
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Volume de recorte (no espaço da câmera)

Recorte (*Clipping*)

Algoritmo de Cyrus-Becker Caixa de recorte convexa



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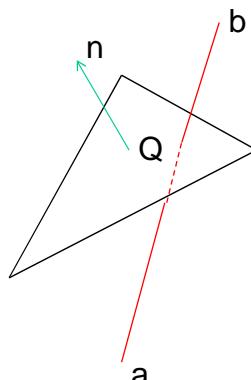
Recorte em 3D (w=1) Interseção segmento-plano

$$P(t) = a + t(b-a)$$

$$f(P(t)) = n(P(t) - Q) = 0$$

$$n((a + t(b-a)) - Q) = 0$$

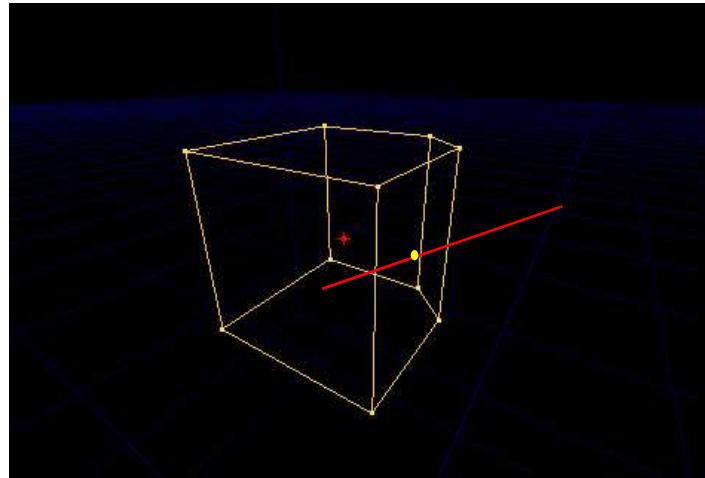
$$t = \frac{n(a - Q)}{n(b - a)}$$



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Recorte em 3D (w=1)

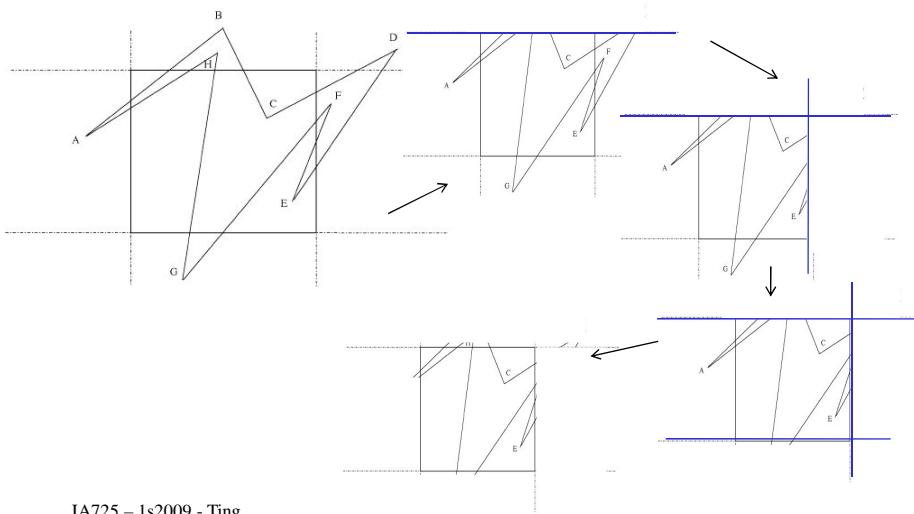
Algoritmo de Liang-Barsky



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Recorte em 2D

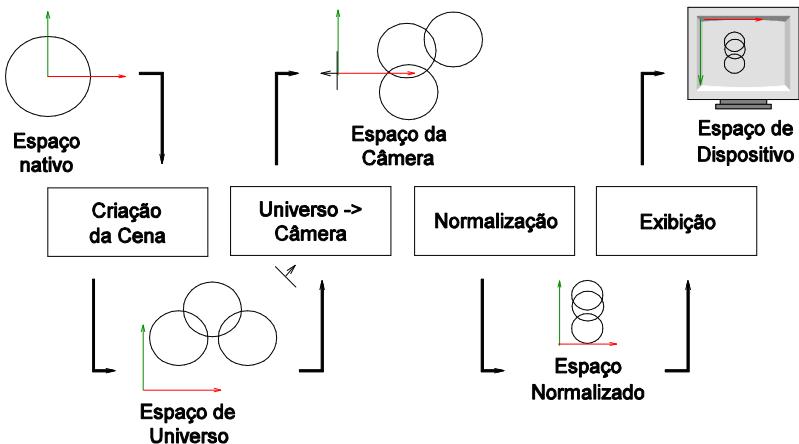
Algoritmo de Sutherland-Hodgman



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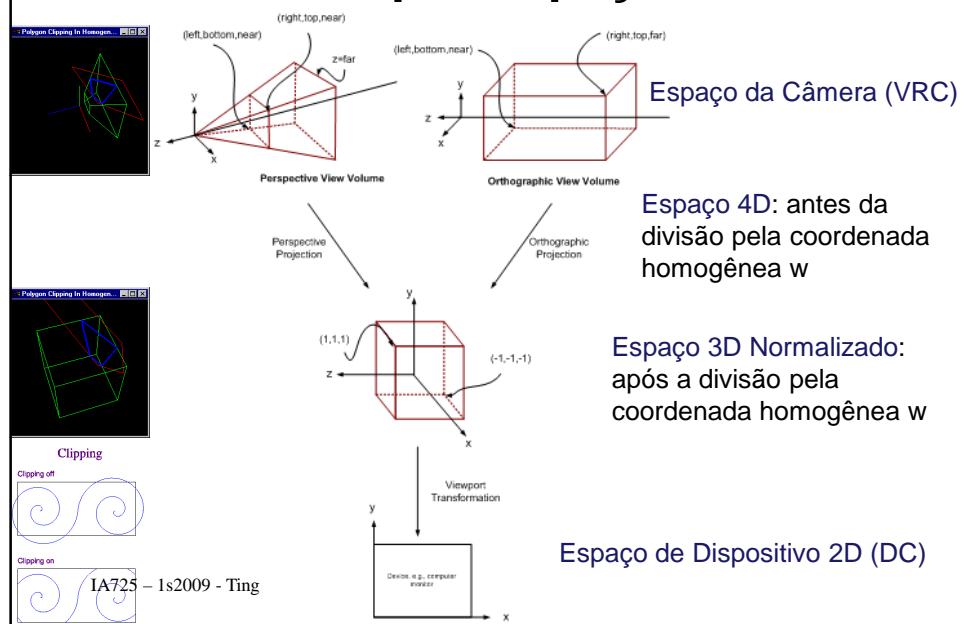
Fluxo de Projeção

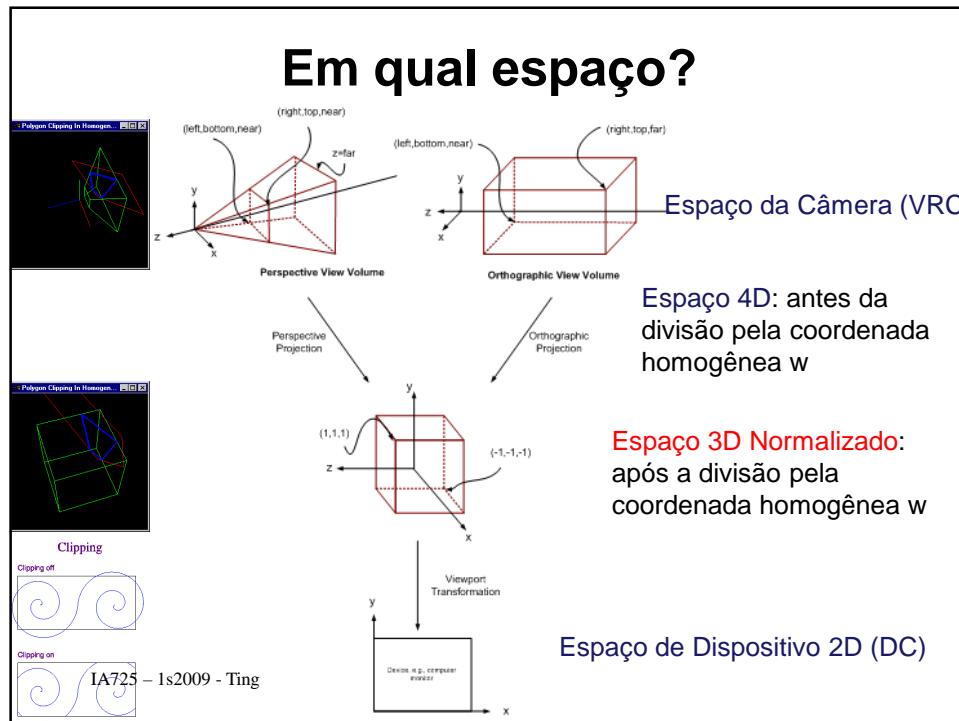
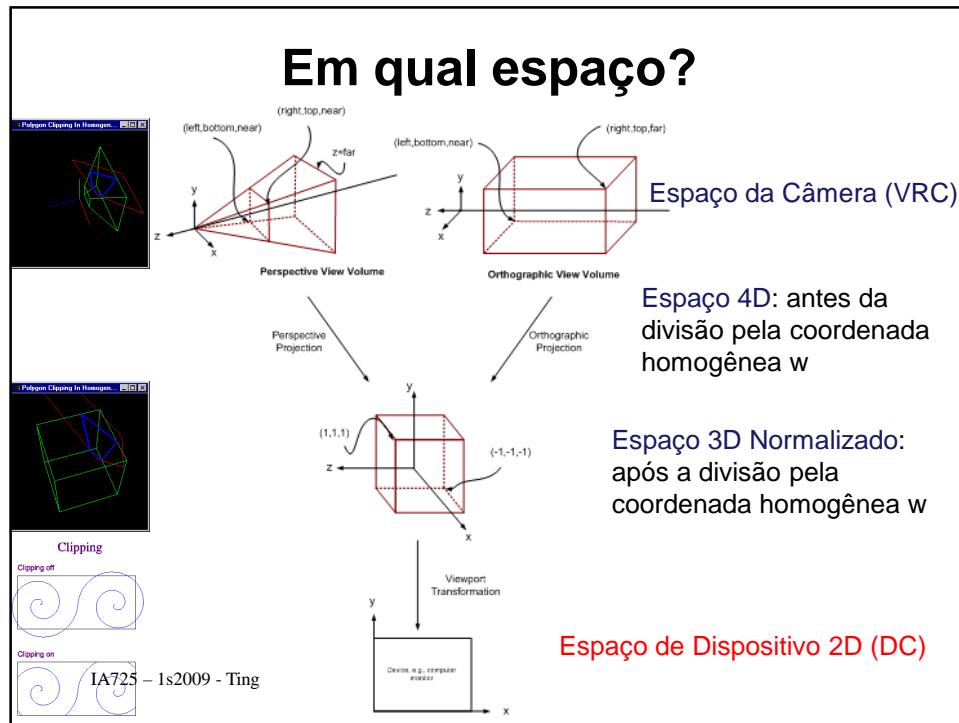
Em qual espaço?



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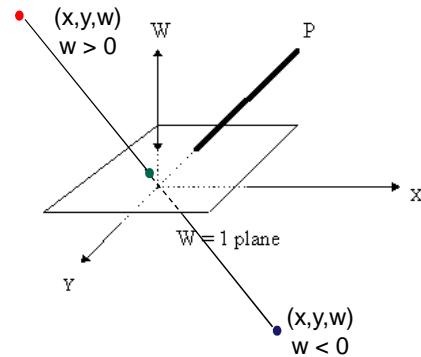
Em qual espaço?





Recorte em 4D ($w \leq 0$)

Após a divisão por w ?

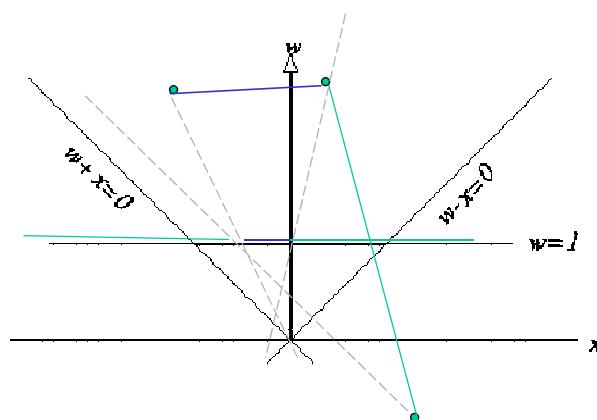


Ambigüidade na projeção $(x/w, y/w, 1)!$

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Recorte em 4D ($w \leq 0$)

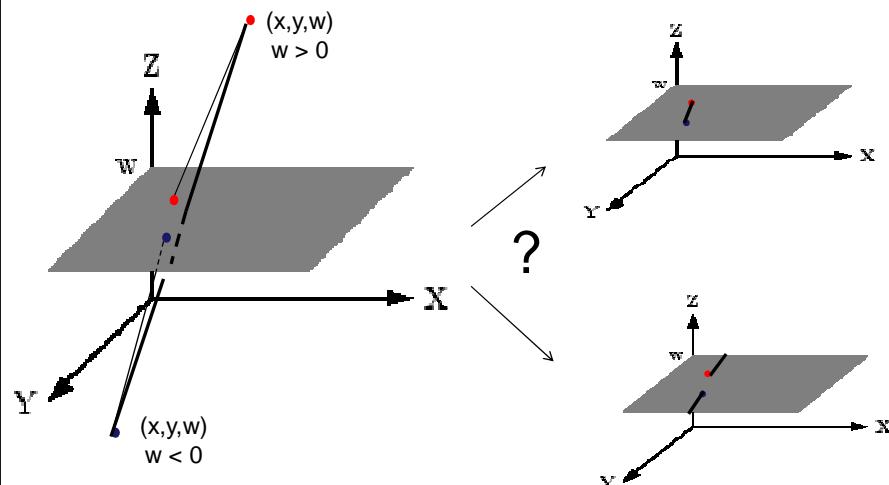
Recorte de um segmento pode resultar em 2 sub-segmentos!



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Recorte em 4D ($w \leq 0$)

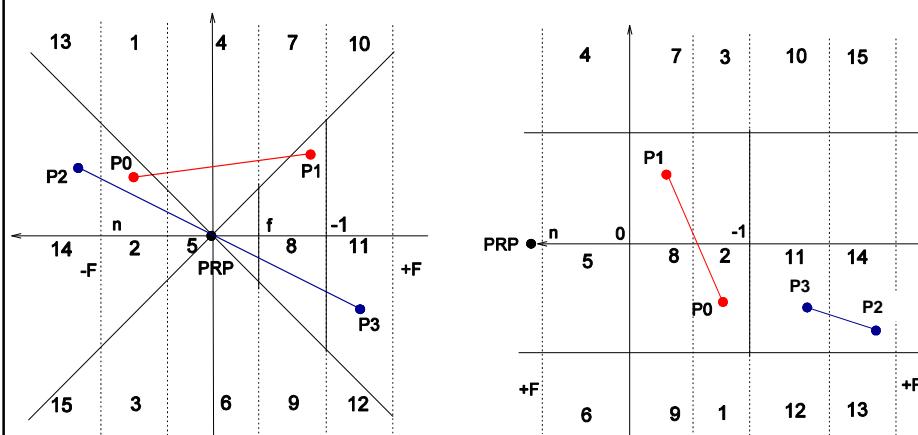
Após a divisão por w ?



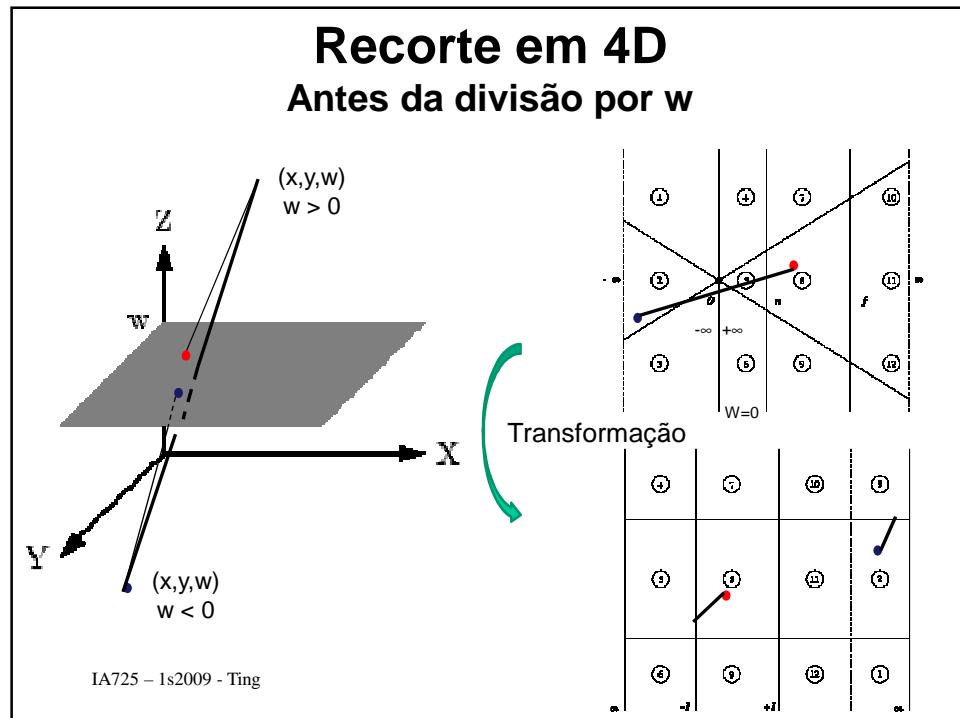
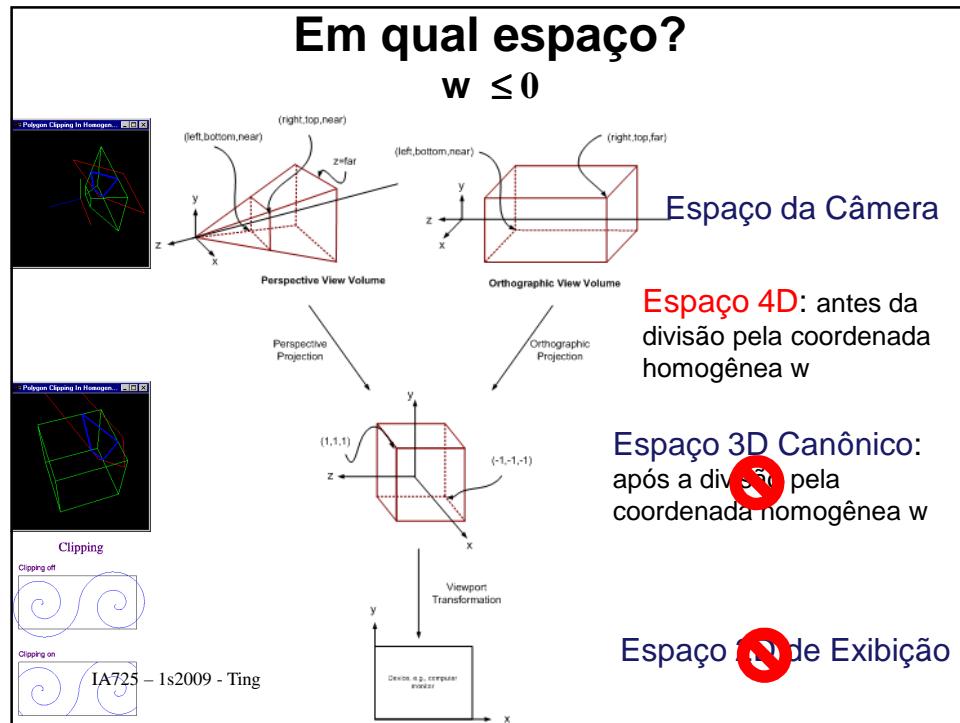
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Recorte em 4D

Após a divisão por w

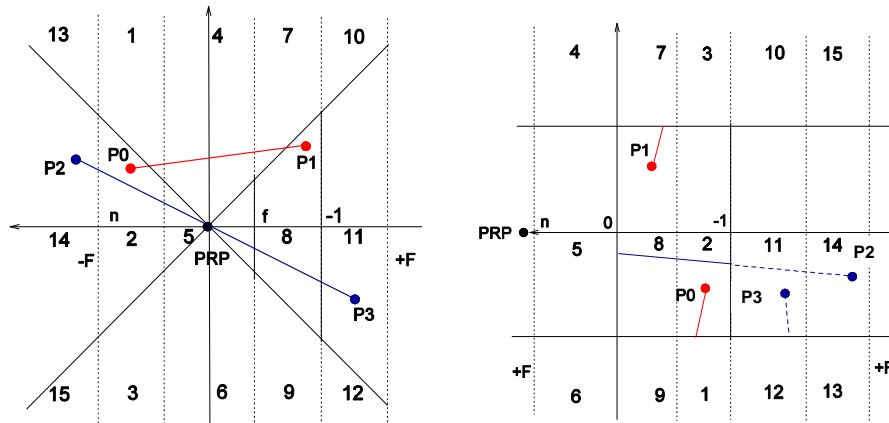


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Recorte em 4D

Antes da divisão por w



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Recorte em 4D

$$-1 \leq \frac{\bar{x}, \bar{y}, \bar{z}}{w} \leq +1$$

$$-w \leq x, y, z \leq w$$

Dado: $P(t) = a + t(b-a)$

Possibilidades:

(entra,sai)

(sai,entra)

Interseção com $x=-w$:

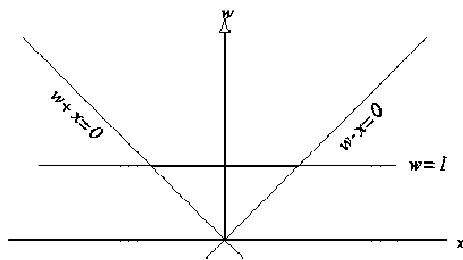
$$w_a + t(w_b - w_a) = -(x_a + t(x_b - x_a))$$

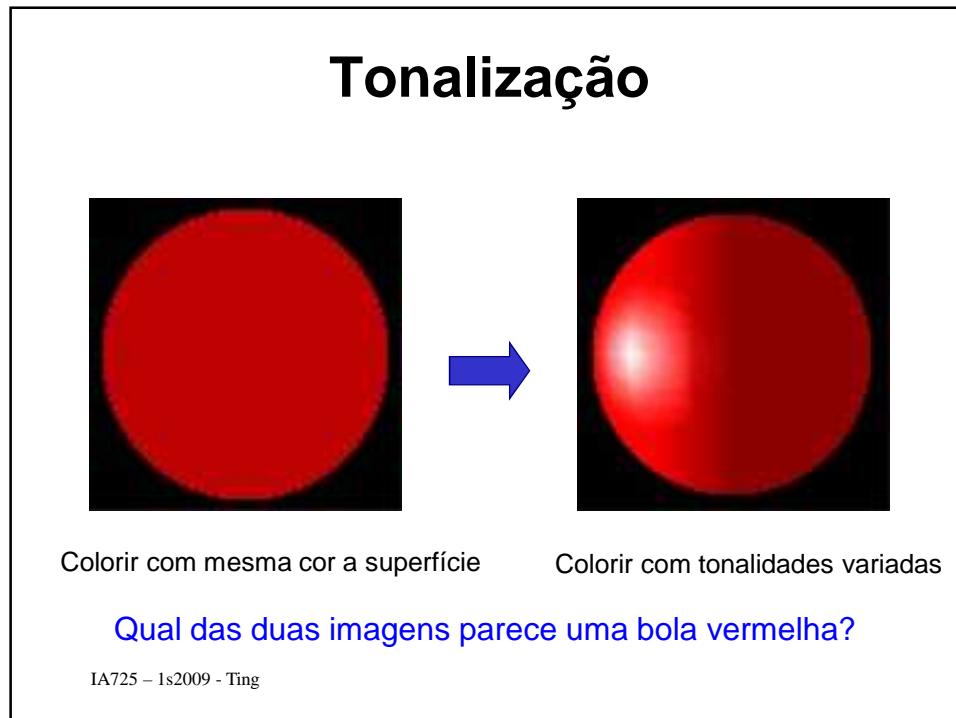
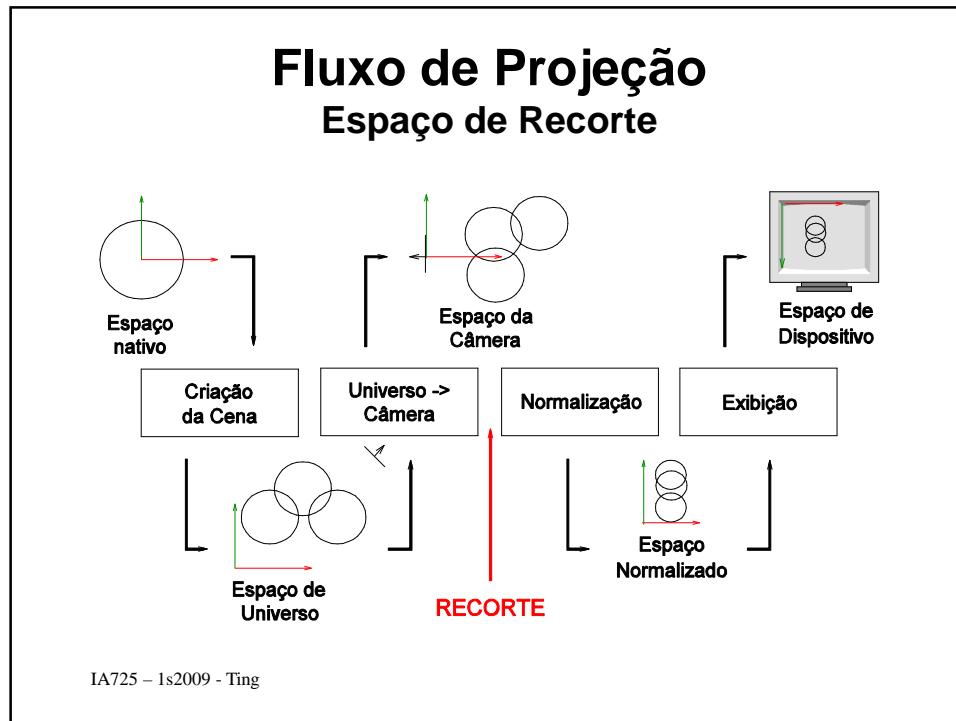
$$t = \frac{w_a + x_a}{(w_a + x_a) - (w_b + x_b)}$$

Analogamente, com

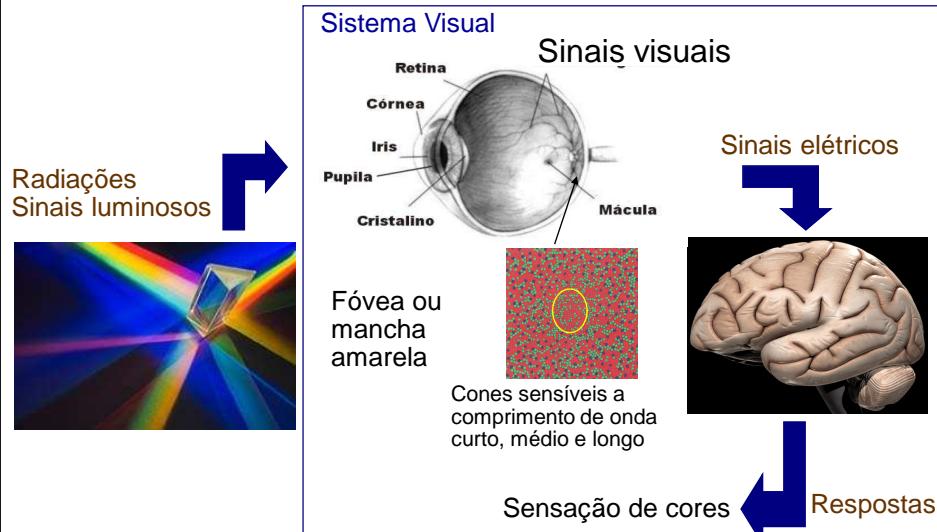
 $x=w, y=-w, y=w, z=-w,$ $z=w$

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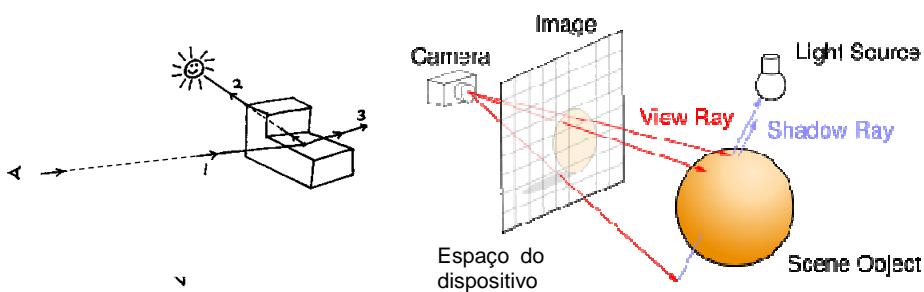


Percepção de Cores



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Luz x Superfícies x Observador

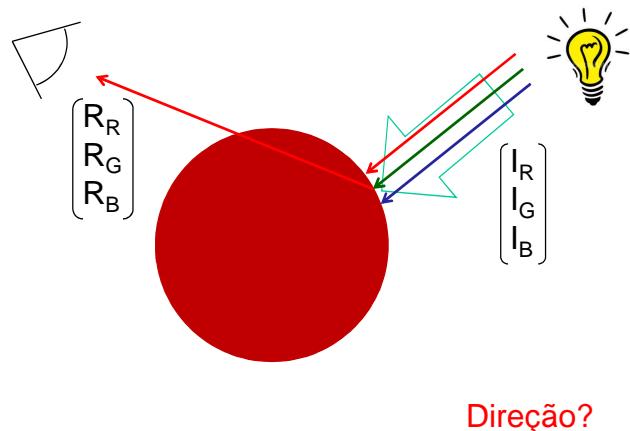


Como se representam radiações luminosas?

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Cor da Luz

Teoria Tricromática

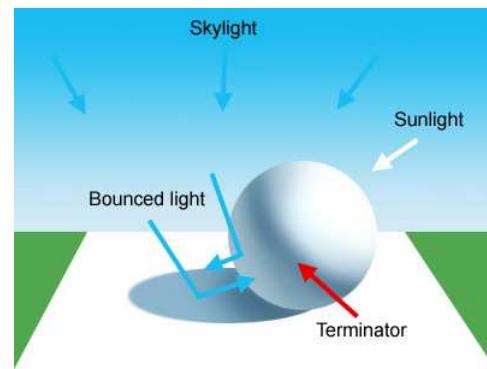
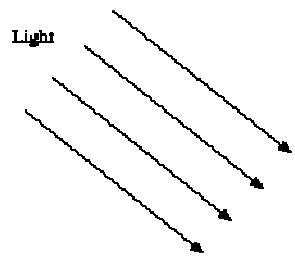


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Fontes de Luz

Fonte Direcional ou Distante

$$P_0 = \begin{pmatrix} x \\ y \\ z \\ 0 \end{pmatrix}$$



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Fontes de Luz

Fonte Pontual

$P_0 = \begin{pmatrix} x \\ y \\ z \\ 1 \end{pmatrix}$

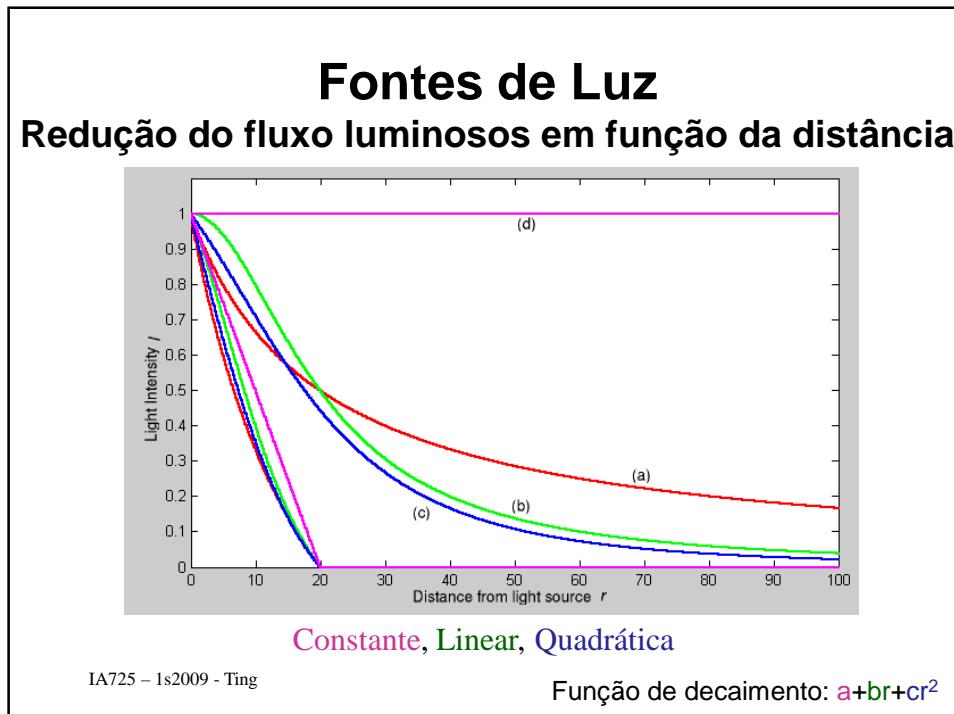
Light Source Centre

Size/Distance

Various Point Lights

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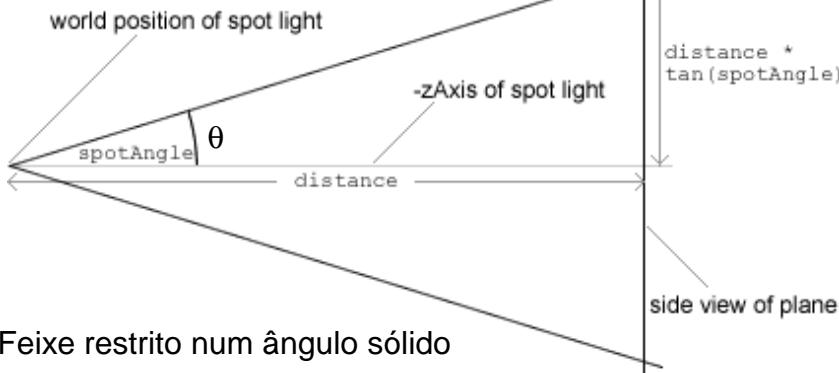
Direção radial



Fontes de Luz

Fonte Spot (Warn)

$$\mathbf{P}_0 = \begin{pmatrix} x \\ y \\ z \\ 1 \end{pmatrix}$$

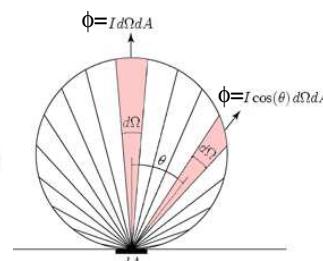
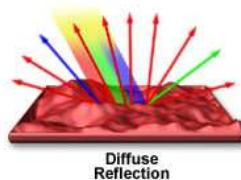


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Modelo de Iluminação Phong

Reflexões Difusas

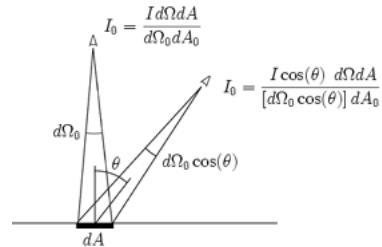
Intensidade luminosa refletida é diretamente proporcional ao cosseno do ângulo θ



Intensidade percebida pelo observador independe da sua posição

$$I_d = k_d I_d \cos \theta$$

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Modelo de Iluminação Phong

Reflexões Especulares



Intensidade luminosa refletida é diretamente proporcional à potência α do cosseno do ângulo β

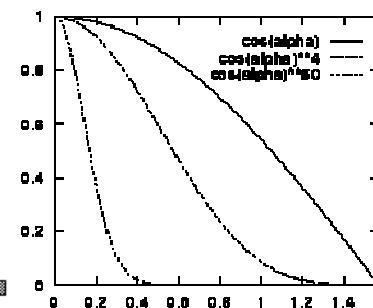
$$I_s = k_s I_s (\cos\beta)^\alpha$$

Position of Max Specular Reflection (R)

$$\beta/2$$

N
θ
θ

V
L
β
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Modelo de Iluminação Phong

Multireflexões

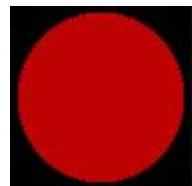


Intensidade luminosa comum para todos os pontos do ambiente

$$I_a = k_a I_a$$

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Modelo de Iluminação Phong



ambiente

Modelo de Phong

$$I_p = k_a I_a + k_d I_d \cos\theta + k_s I_s (\cos\beta)^\alpha$$

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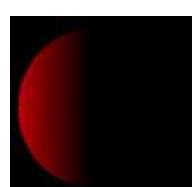
Modelo de Iluminação Phong



ambiente

Modelo de Phong

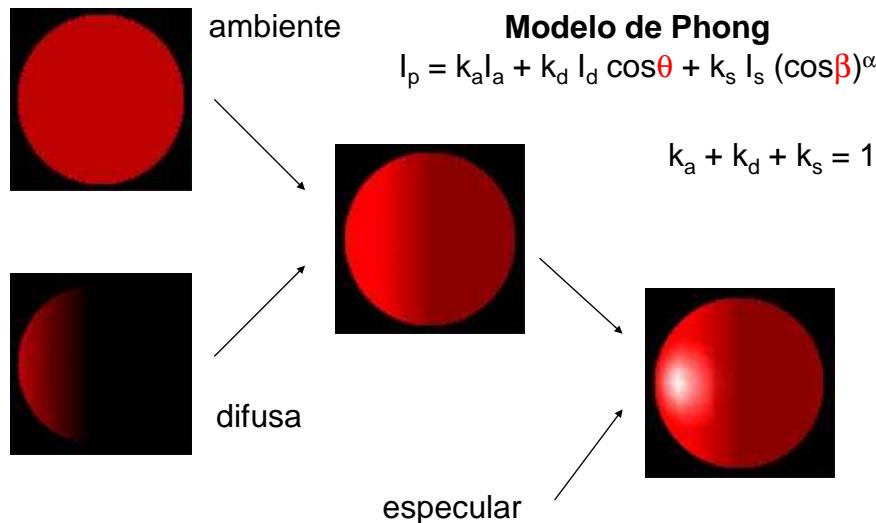
$$I_p = k_a I_a + k_d I_d \cos\theta + k_s I_s (\cos\beta)^\alpha$$



difusa

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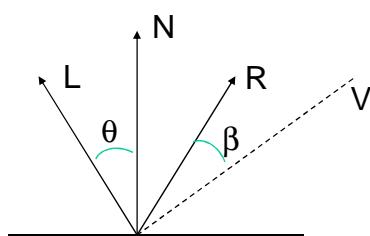
Modelo de Iluminação Phong



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Modelo de Iluminação Phong

$$I_p = k_a I_a + k_d I_d \cos\theta + k_s I_s (\cos\beta)^\alpha$$



$$\cos\theta = N \cdot L / (|N||L|)$$

$$\cos\beta = R \cdot V / (|R||V|)$$

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

Vetor Normal no cálculo da componente especular!!

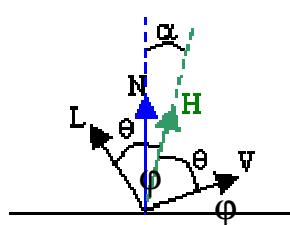
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Modelo de Phong Modificado

$$I_p = k_a I_a + k_d I_d \cos\theta + k_s I_s (\cos\varphi)^{\alpha'}$$

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

Intensidade luminosa refletida é diretamente proporcional à potência α' do cosseno do ângulo θ



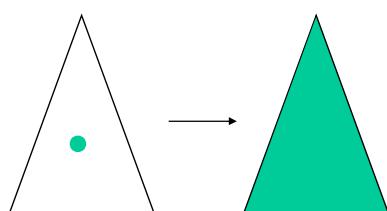
Vantagem: Quando a fonte luminosa e o observador forem distantes, H é constante.

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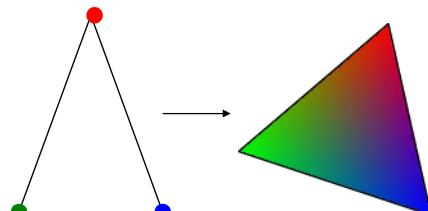
Tonalização (*Shading*)

Calcular as propriedades gráficas ou geométricas em algumas amostras e propagá-las para o restante dos pontos

Cópia (*Flat shading*)

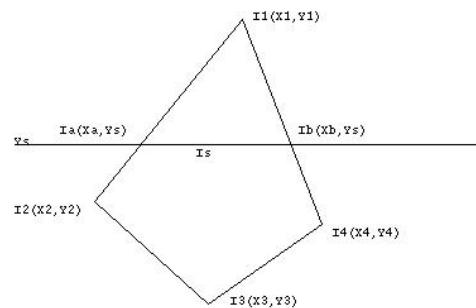


Interpolação (*Gouraud shading*)



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Tonalização Interpolação Linear de Intensidades



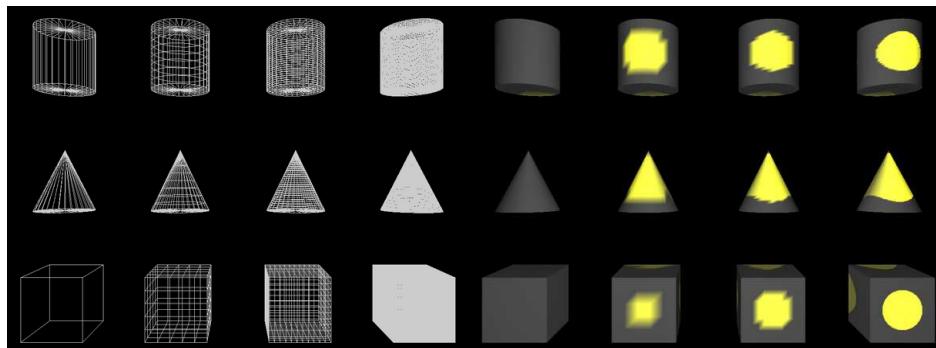
Gouraud Shading
Interpolação linear de intensidades

$$I_a(t) = t I_1 + (1-t) I_2$$

$$I_b(t) = t I_3 + (1-t) I_4$$

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Tonalização Interpolação Linear

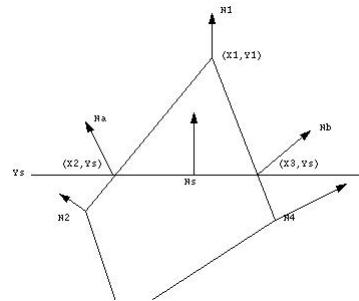


Resultados distintos para diferentes triangulações
Perda de pontos de brilho

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Tonalização

Interpolação Linear de Intensidades



Phong Shading

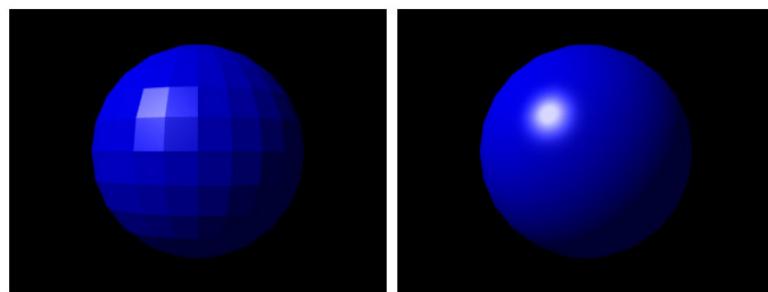
Interpolação linear de vetores normais

$$N_a(t) = t N_1 + (1-t) N_2$$

$$N_b(t) = t N_1 + (1-t) N_4$$

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Tonalização



FLAT SHADING

PHONG SHADING

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GOURAUD SHADING

Tonalização

Phong Shading Demo Gouraud Shading Demo

Phong Shading Demo Gouraud Shading Demo

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Rasterização: Fragmentos

Conversão de informações vetoriais em fragmentos

Discretização

Red

Green

Blue

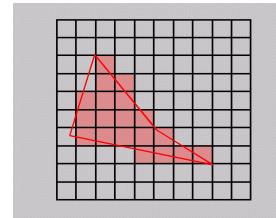
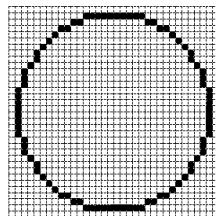
pixel

fragmentos

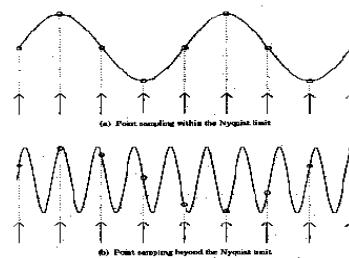
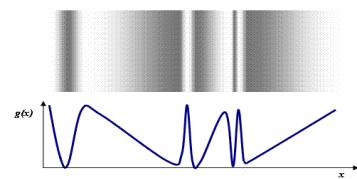
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Duas Abordagens

Geométrica (Rasterização): pixels que sobrepõem os objetos vetoriais

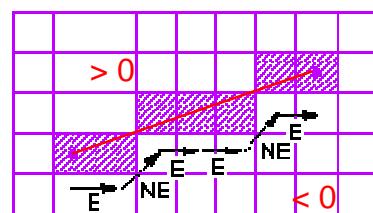


Espectral (Amostragem): amostragem da função de intensidade definida no domínio espacial



Rasterização de Segmentos Algoritmo de Ponto Médio

$$f(x,y) = (y_1 - y_F) x + (x_F - x_1) y + C = -\Delta y x + \Delta x y + C = 0$$



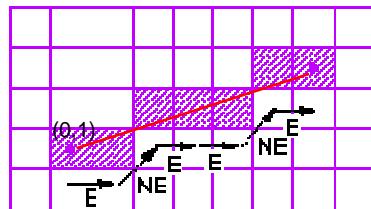
Se $(y_1 - y_0) < (x_1 - x_0)$, ou $\Delta y < \Delta x$,

Função de Decisão

$f(x_0+1, y_0+0.5) \geq 0 \rightarrow f(x_0+1, y_0+0.5) \text{ acima da reta } f(x,y) \rightarrow E$
 $f(x_0+1, y_0+0.5) < 0 \rightarrow f(x_0+1, y_0+0.5) \text{ abaixo da reta } f(x,y) \rightarrow NE$

Rasterização de Segmentos

Algoritmo de Ponto Médio



$$y = (1/3)x + 1 \rightarrow f(x,y) = y - (1/3)x - 1; x_0 = 0; y_0 = 1;$$

$f(0+1, 1+0.5) > 0 \rightarrow f(1, 1.5) = 1/6$ acima da reta $f(x,y)$ $\rightarrow E$
 $f(1+1, 1+0.5) < 0 \rightarrow f(2, 2.5) = -1/6$ abaixo da reta $f(x,y)$ $\rightarrow NE$
 $f(2+1, 2+0.5) < 0 \rightarrow f(3, 3) = 0.5$ acima da reta $f(x,y)$ $\rightarrow E$

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Rasterização de Segmentos

Algoritmo de Ponto Médio

Como obter $f(x_0+2, y_{i+2})$ de forma eficiente?

➤ Se a direção E for escolhida $y_{i+1} = y_i$:

$$\begin{aligned}
 f(x_{i+2}, y_{i+2}) : f(x_i+2, y_i+0.5) \\
 f(x_i+2, y_i+0.5) &= -\Delta y (x_i+2) + \Delta x (y_i+0.5) + C \\
 &= -\Delta y (x_i+1) - \Delta y + \Delta x (y_i+0.5) + C \\
 &= f(x_i+1, y_i+0.5) - \Delta y \\
 f(x_i+2, y_i+0.5) &= f(x_i+1, y_i+0.5) - \Delta y
 \end{aligned}$$

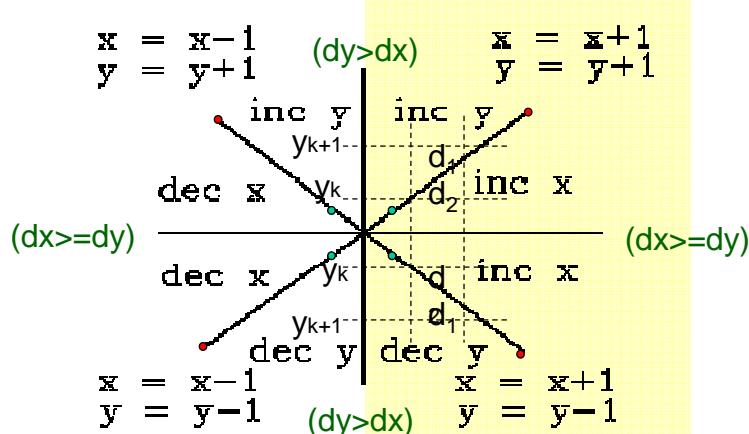
➤ Se a direção NE for escolhida $y_{i+1} = y_i + 1$:

$$\begin{aligned}
 f(x_{i+2}, y_{i+2}) : f(x_i+2, y_i+1.5) \\
 f(x_i+2, y_i+1.5) &= -\Delta y (x_i+2) + \Delta x (y_i+1.5) + C \\
 &= -\Delta y (x_i+1) - \Delta y + \Delta x (y_i+0.5) + \Delta x + C \\
 &= f(x_i+1, y_i+0.5) - \Delta y + \Delta x \\
 f(x_i+2, y_i+1.5) &= f(x_i+1, y_i+0.5) - \Delta y + \Delta x
 \end{aligned}$$

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Rasterização de Segmentos

Linhas: Todos os possíveis casos



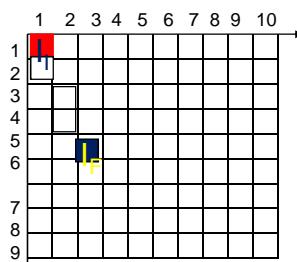
Se invertermos os pontos extremos adequadamente, reduzimos
em 4 casos

Rasterização de Segmentos

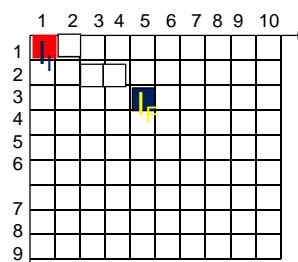
Cor em cada pixel

Interpolação linear

$$I_{i+1} = I_i + 1/(\text{maior variação}) (I_F - I_i)$$



$$I_{i+1} = I_i + 1/(\Delta y) (I_F - I_i)$$

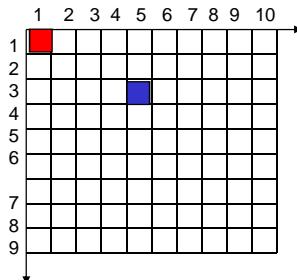


$$I_{i+1} = I_i + 1/(\Delta x) (I_F - I_i)$$

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Exemplo 1

Rasterize o segmento definido pelos pontos $P_I=(1,1)$ e $P_F=(5,3)$
 $(\Delta x = 4) \geq (\Delta y = 2) \rightarrow x$ “anda” em passo unitário



$$\Delta y = 2 \quad \Delta x = 4$$

$$f(x,y) = y - 0.5x - 0.5$$

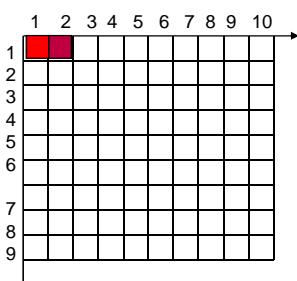
$$d_0 = f(1+1, 1+0.5) = 0$$

$$d_0 \geq 0 \rightarrow y_1 = y_0$$

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Exemplo 1

Rasterize o segmento definido pelos pontos $P_I=(1,1)$ e $P_F=(5,3)$
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$$\Delta y = 2 \quad \Delta x = 4$$

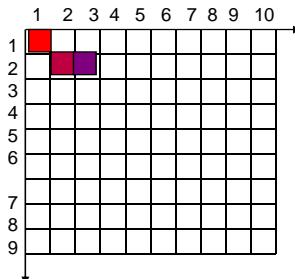
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$$y_1 = y_0 \rightarrow d_1 = d_0 - \Delta y = -2$$

$$d_1 < 0 \rightarrow y_2 = y_1 + 1$$

Exemplo 1

Rasterize o segmento definido pelos pontos $P_I=(1,1)$ e $P_F=(5,3)$
 $(\Delta x = 4) \geq (\Delta y = 2)$ x “anda” em passo unitário



$$\Delta y = 2 \quad \Delta x = 4$$

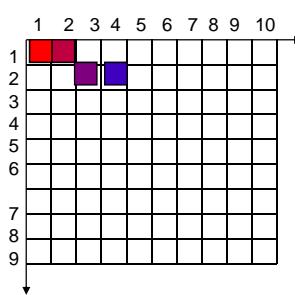
$$y_2 = y_1 + 1 \rightarrow d_2 = d_1 - \Delta y + \Delta x = 0$$

$$d_2 \geq 0 \rightarrow y_3 = y_2$$

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Exemplo 1

Rasterize o segmento definido pelos pontos $P_I=(1,1)$ e $P_F=(5,3)$
 $(\Delta x = 4) \geq (\Delta y = 2)$ x “anda” em passo unitário



$$\Delta y = 2 \quad \Delta x = 4$$

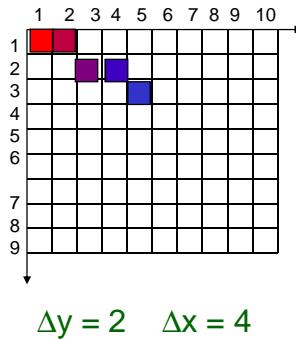
$$y_3 = y_2 \rightarrow d_3 = d_2 - \Delta y = -2$$

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$$d_3 < 0 \rightarrow y_4 = y_3 + 1$$

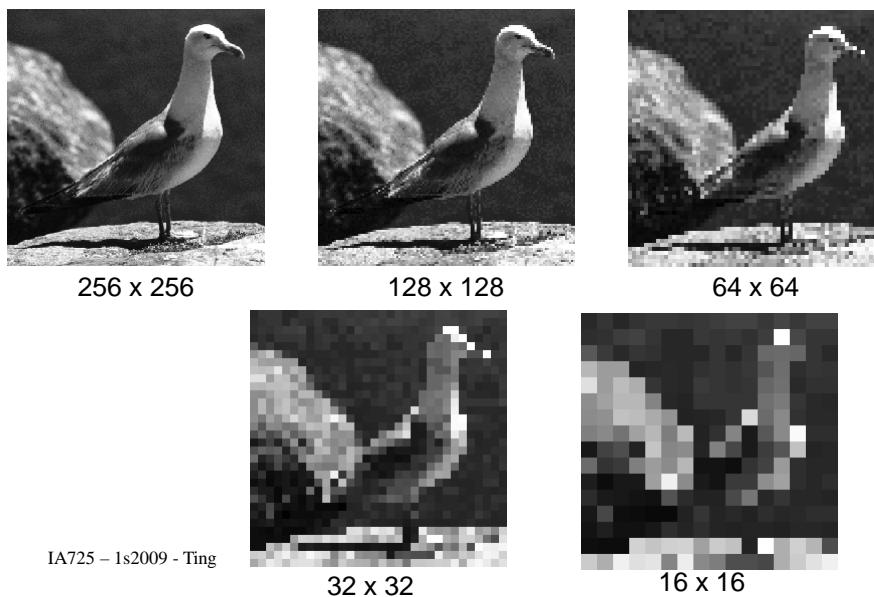
Exemplo 1

Rasterize o segmento definido pelos pontos $P_I=(1,1)$ e $P_F=(5,3)$
 $(\Delta x = 4) \geq (\Delta y = 2)$ x “anda” em passo unitário



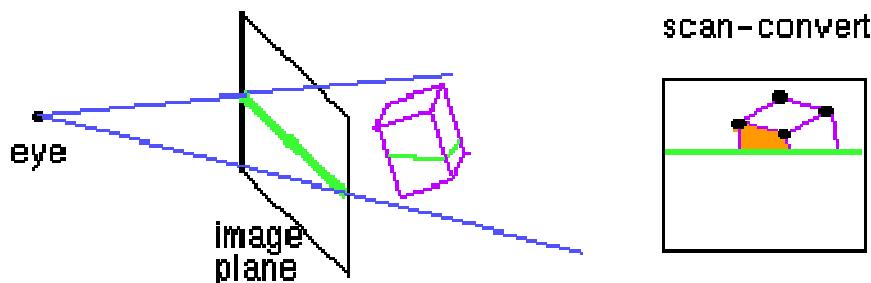
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Rasterização



Rasterização de Polígonos

Princípio de Scanline

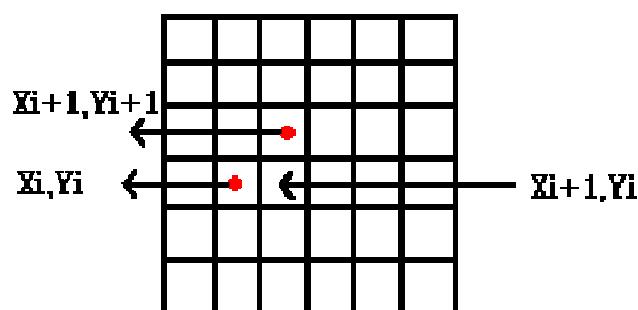


1. Rasterizar borda com DDA
2. Utilizar coerência para preenchimento de linhas

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Rasterização de Segmentos

DDA



$$Y = (\Delta y / \Delta x) X + b$$

$$m = \Delta y / \Delta x = (Y_{i+1} - Y_i) / (X_{i+1} - X_i);$$

$$m \leq 1: Y_{i+1} = Y_i + m$$

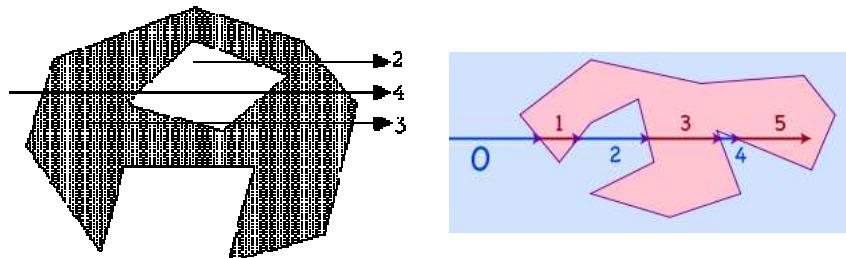
$$m > 1 : X_{i+1} = X_i + 1/m$$

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Rasterização de Polígonos

Teste de Pertinência

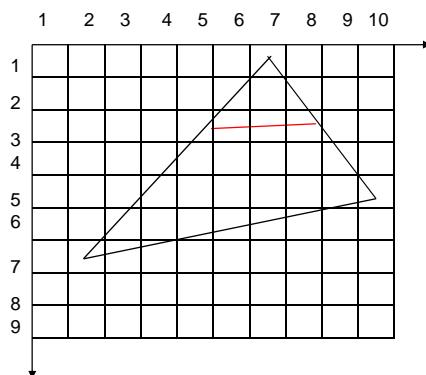
Ray Casting



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Rasterização de Polígonos

Scanline



Varredura por linha

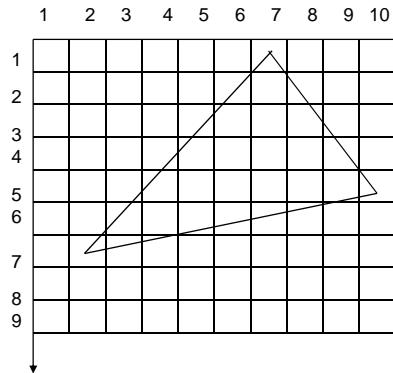
Para cada linha:

1. Determinar os pontos de interseção
2. Ordenar os pontos de interseção
3. Preencher o interior

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Rasterização de Polígonos

Scanline



1. Inserir as arestas na tabela de arestas (ET);

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Rasterização de Polígonos

Scanline

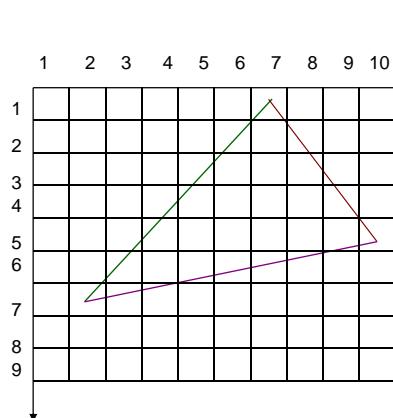


Tabela de Arestas

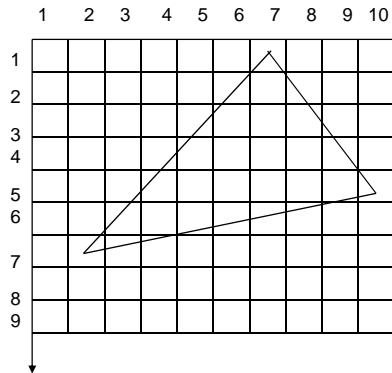
	y_{max}	x	$1/m$	
	7	7	3/4	5 7 -5/6
	7	10	-4	

	7	10	-4	
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Rasterização de Polígonos

Scanline



1. Inserir as arestas na tabela de arestas (ET);
2. Setar a linha $y=1$ como ativa;
3. Inicializar a tabela de arestas ativa (AET) para linha ativa, ordenando as células em relação à coordenada x
4. Preencher os intervalos

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Rasterização de Polígonos

Scanline

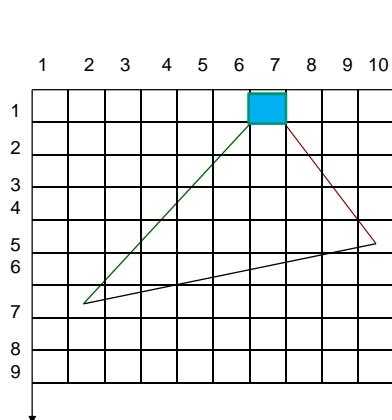


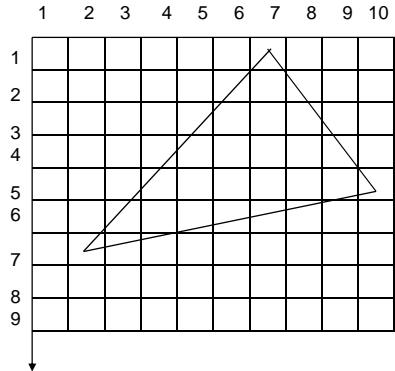
Tabela de Areastas

	y_{max}	x	$1/m$	
	7	7	3/4	5 7 -5/6
	7	10	-4	

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Rasterização de Polígonos

Scanline



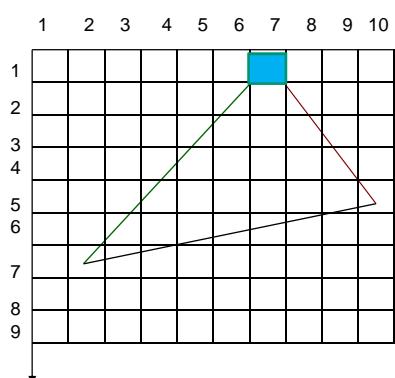
1. Inserir as arestas na tabela de arestas (ET);
2. Setar a linha $y=1$ como ativa;
3. Inicializar a tabela de arestas ativa (AET) para linha ativa, ordenando as células em relação à coordenada x
4. Preencher os intervalos
5. Se a próxima linha é menor que y_{max} , atualize x e transfere a célula para a próxima linha

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Rasterização de Polígonos

Scanline

Tabela de Arestas

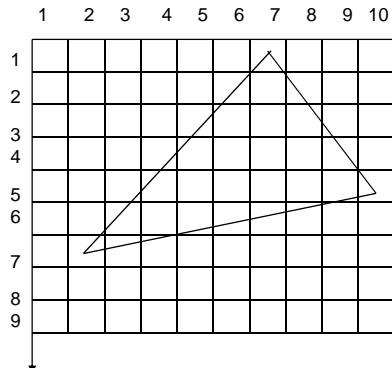


	y_{max}	x	$1/m$	
7	31/4	3/4		5 37/6-5/6 \
7	10	-4		

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Rasterização de Polígonos

Scanline



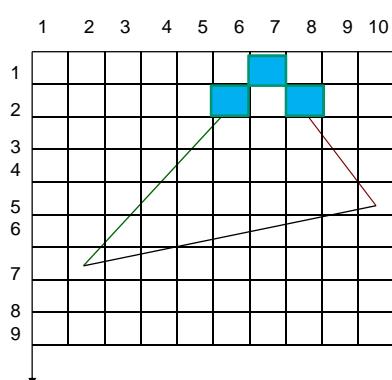
IA725 – 1s2009 - Ting

1. Inserir as arestas na tabela de arestas (ET);
2. Setar a linha $y=1$ como ativa;
3. Inicializar a tabela de arestas ativa (AET) para linha ativa, ordenando as células em relação à coordenada x
4. Preencher os intervalos
5. Se a próxima linha é maior que y_{max} , atualize x e transfere a célula para a próxima linha
6. Se há arestas na ET, ir para (3).

Rasterização de Polígonos

Scanline

Tabela de Arestas



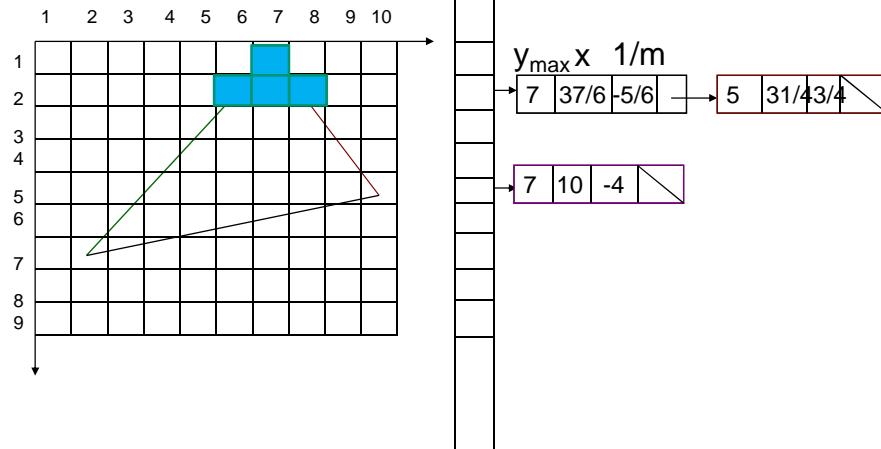
	y_{max}	x	$1/m$	
	7	37/6	-5/6	5 31/43/4
	7	10	-4	

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Rasterização de Polígonos

Scanline

Tabela de Arestas

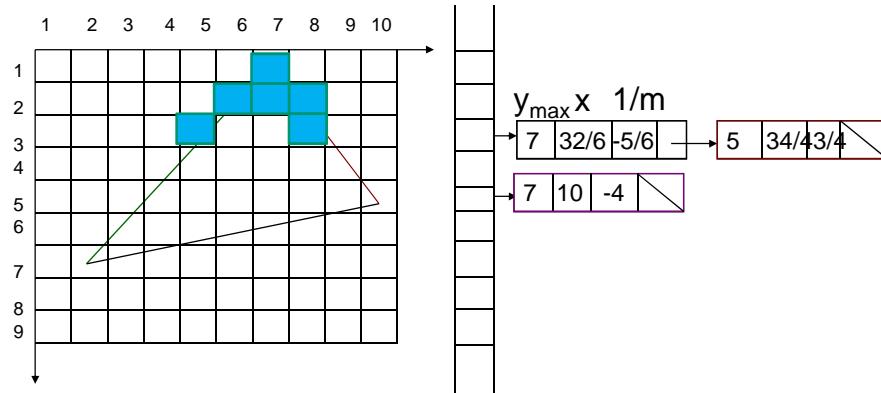


IA725 – 1s2009 - Ting

Rasterização de Polígonos

Scanline

Tabela de Arestas

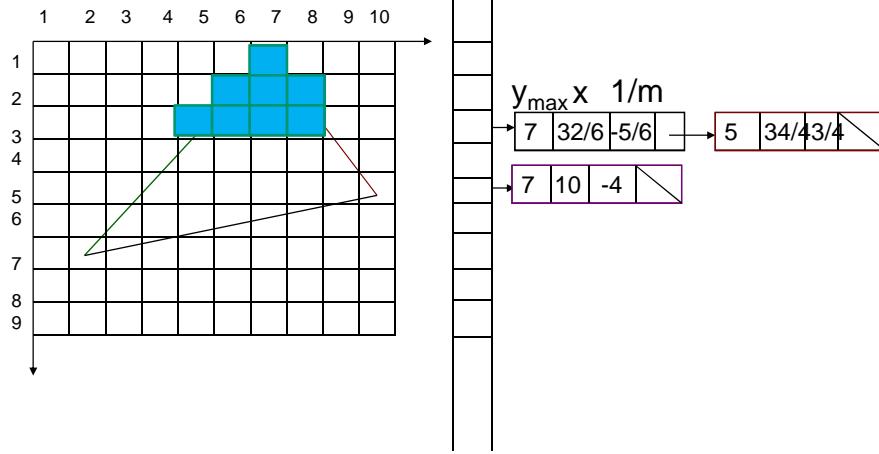


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Rasterização de Polígonos

Scanline

Tabela de Arestas

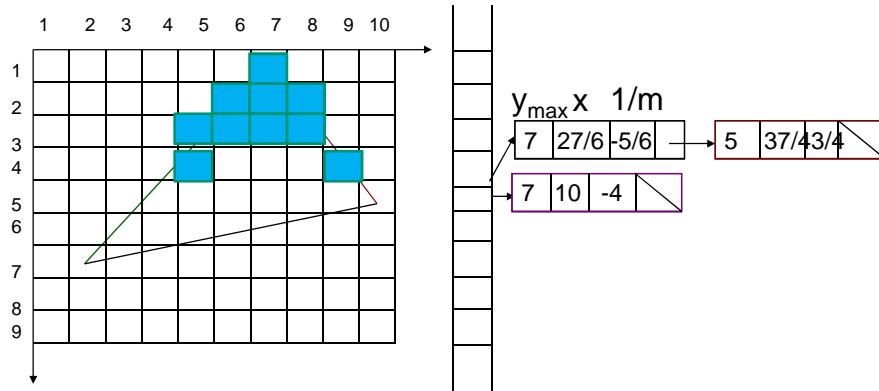


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Rasterização de Polígonos

Scanline

Tabela de Arestas

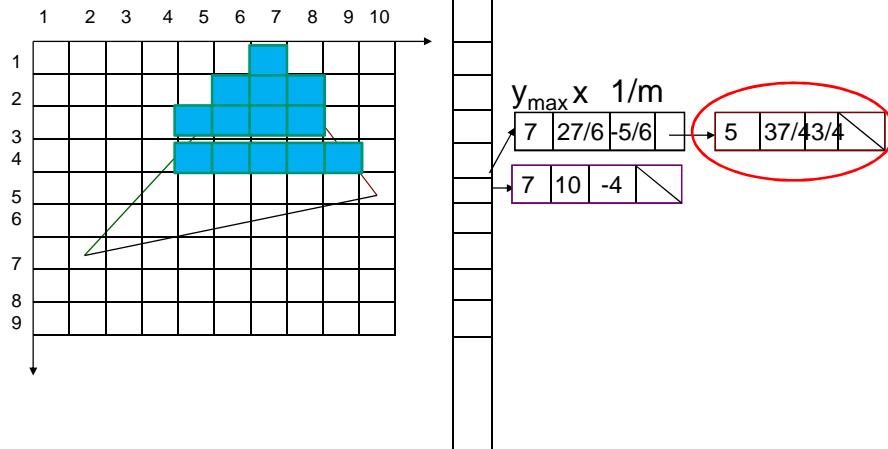


IA725 – 1s2009 - Ting

Rasterização de Polígonos

Scanline

Tabela de Arestas

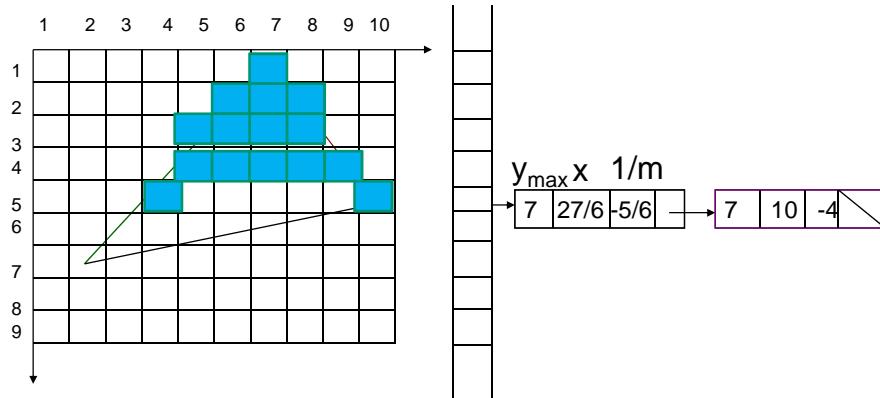


IA725 – 1s2009 - Ting

Rasterização de Polígonos

Scanline

Tabela de Arestas

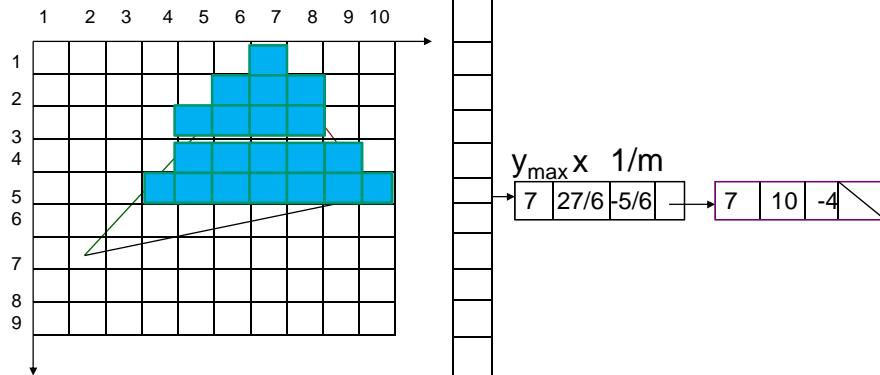


IA725 – 1s2009 - Ting

Rasterização de Polígonos

Scanline

Tabela de Arestas

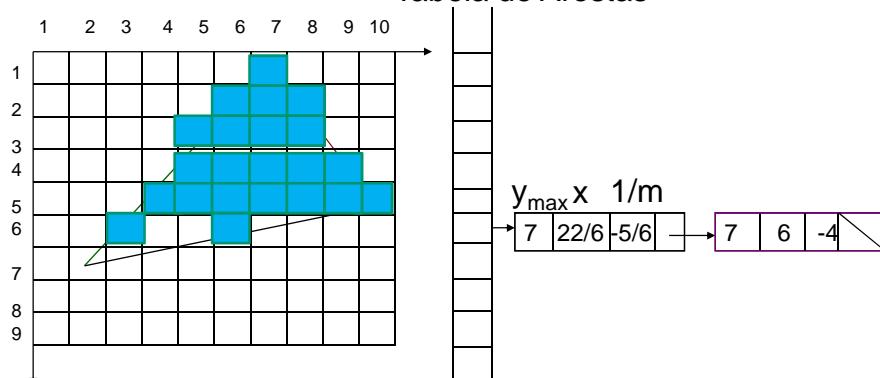


IA725 – 1s2009 - Ting

Rasterização de Polígonos

Scanline

Tabela de Arestas

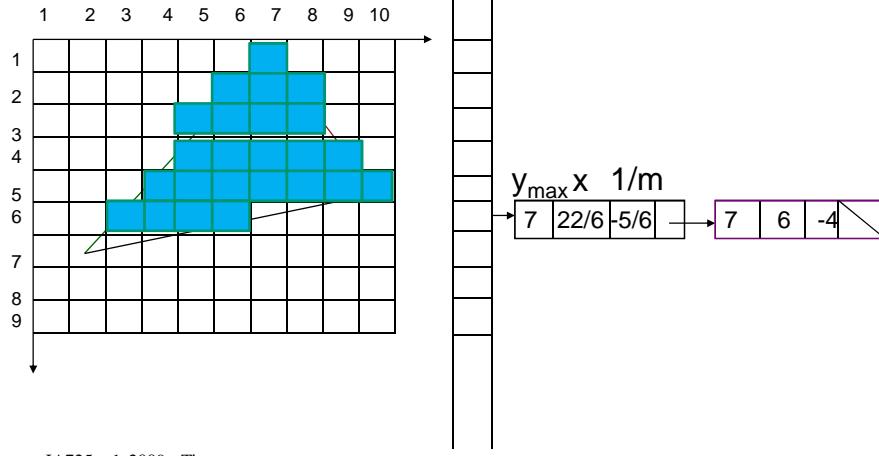


IA725 – 1s2009 - Ting

Rasterização de Polígonos

Scanline

Tabela de Arestas

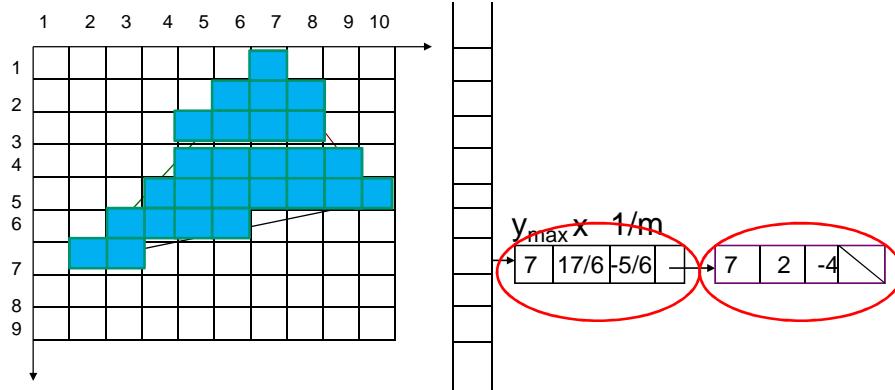


IA725 – 1s2009 - Ting

Rasterização de Polígonos

Scanline

Tabela de Arestas

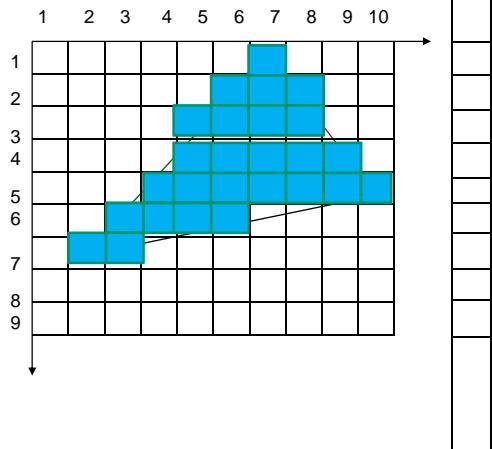


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Rasterização de Polígonos

Scanline

Tabela de Arestas

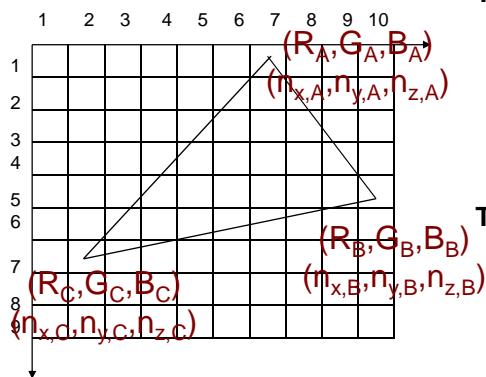


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Rasterização de Polígonos

Scanline - Variações

Tonalização de Gouraud:



A intensidade nos vértices é computada e a intensidade dos restantes pixels, interpolada linearmente.

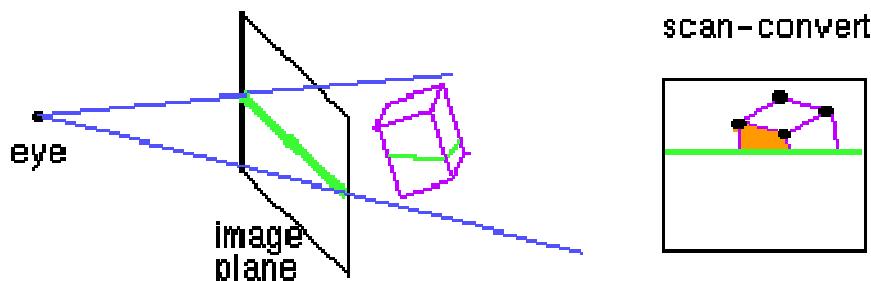
Tonalização de Phong:

O vetor normal nos vértices é computado e o vetor normal dos restantes pixels, interpolado linearmente.

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Rasterização de Polígonos

Princípio de Scanline



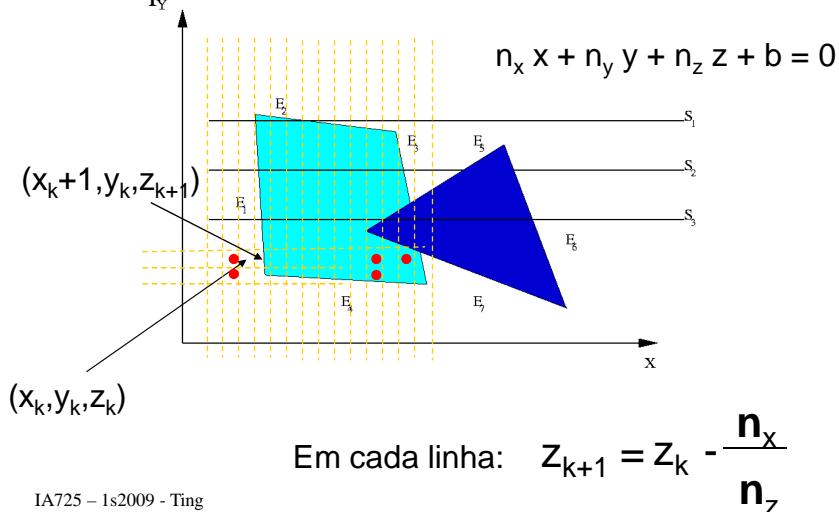
Profundidade?

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Rasterização de Polígonos

Scanline - Variações

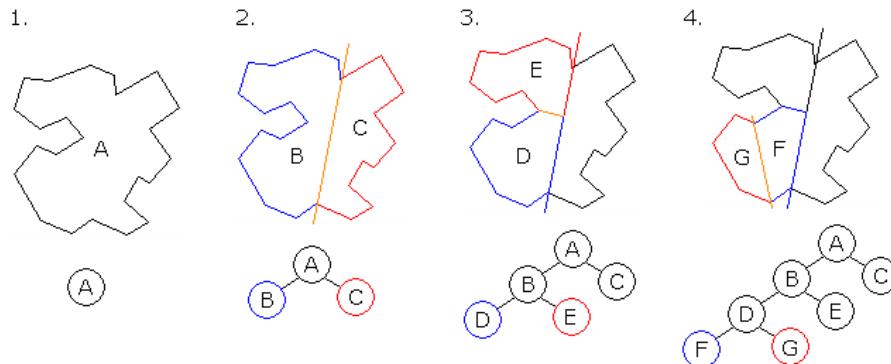
- Valor de profundidade obtido incrementalmente



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Árvore BSP

Partição Binária do Espaço

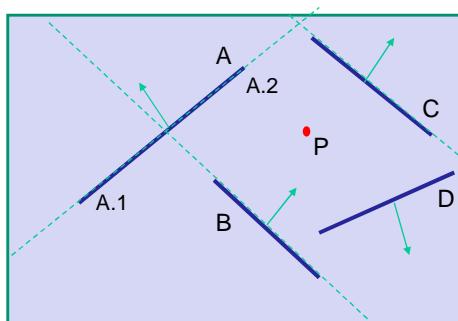


Como distinguir os dois sub-espacos em relação a um plano?
Como resolver ambigüidades?

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Árvore BSP

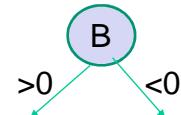
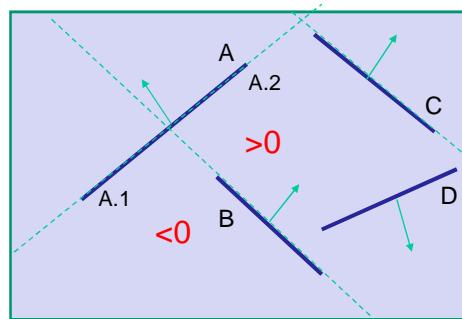


$P \cdot n + b > 0 ; P \cdot n + b = 0 ; P \cdot n + b < 0$
Subdividir para eliminar ambigüidades.

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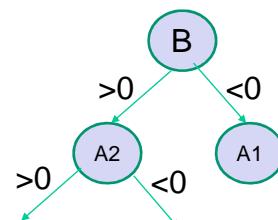
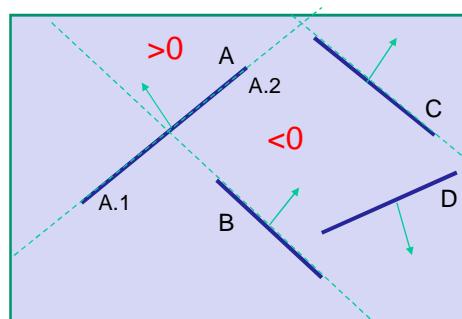
EA978 – 2/2008 - Profa. Ting

Árvore BSP



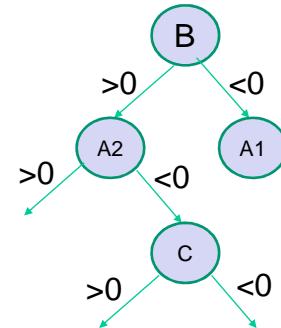
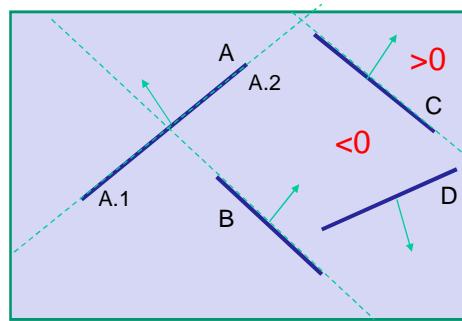
IA725 – 1s2009 - Ting
EA978 – 2/2008 - Profa. Ting

Árvore BSP



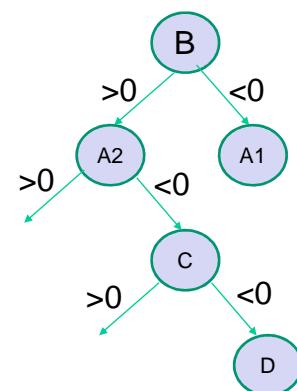
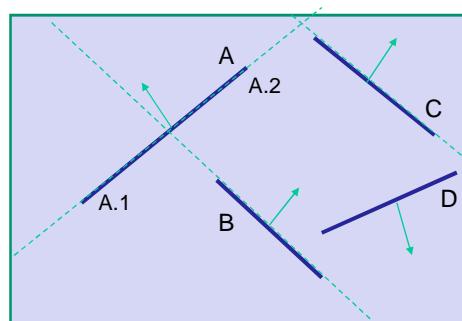
IA725 – 1s2009 - Ting
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Árvore BSP



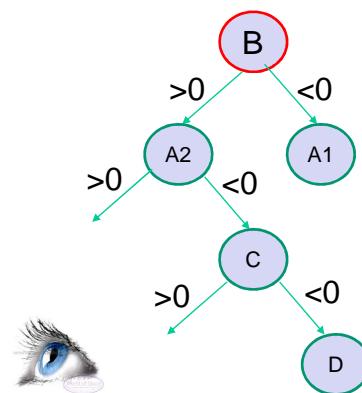
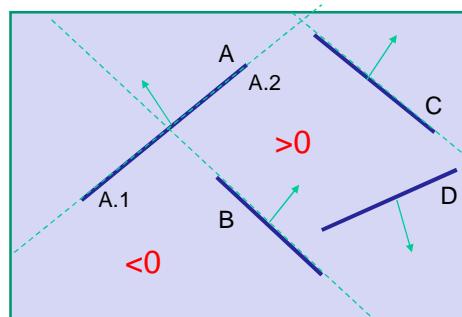
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Árvore BSP



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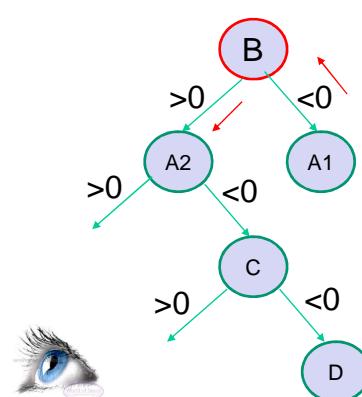
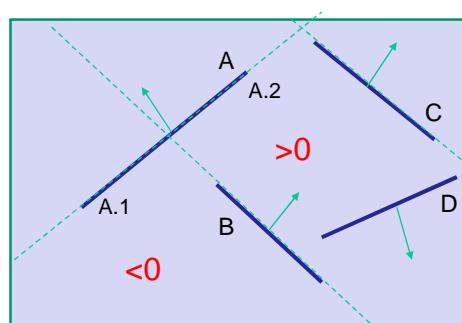
Árvore BSP em Visibilidade



Em relação à raiz da árvore (faceta B), o observador está no sub-espacô >0. Em relação a este observador, o que estiver no sub-espacô >0 vai ocultar B, que pode ocultar tudo que estiver no sub-espacô <0.

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EA978 – 2/2008 - Profa. Ting

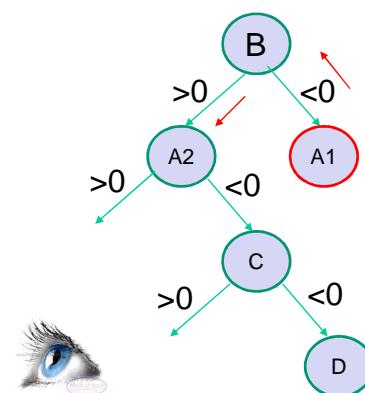
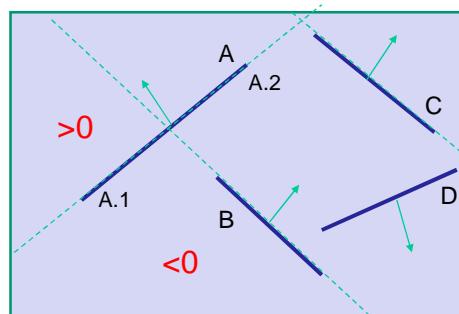
Árvore BSP em Visibilidade



Se ordenarmos as faces, de longe para perto em relação ao observador, teremos que pegar as no sub-espacô <0, B e as no sub-espacô > 0.

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EA978 – 2/2008 - Profa. Ting

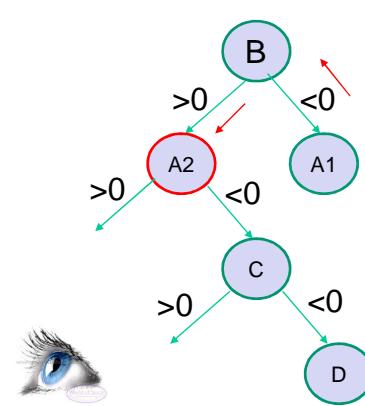
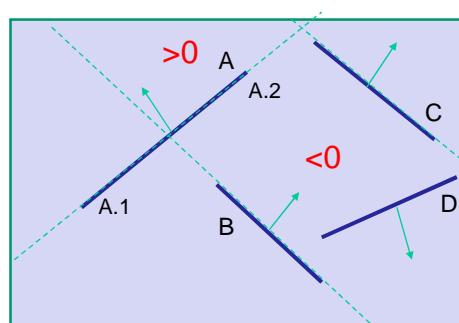
Árvore BSP em Visibilidade



No sub-espaco <0 em relacao a B so h谩 uma face, A1. A ordena玢o 茅 trivial..

IA725 – 1s2009 - Ting
EA978 – 2/2008 - Profa. Ting

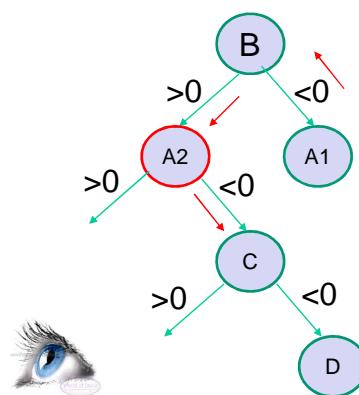
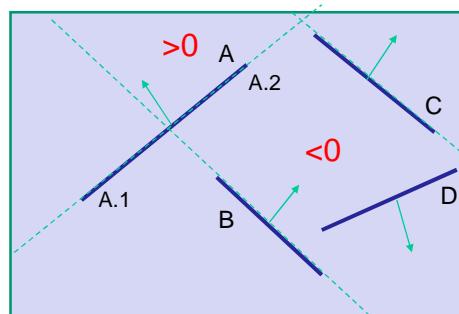
Árvore BSP em Visibilidade



No sub-espaco >0 em relacao a B h谩 3 faces. Qual 茅 a ordena玢o dessas 3 faces em relacao ao observador?. Aplicando a mesma regra, para a sub-ŕvore de raiz A2.

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EA978 – 2/2008 - Profa. Ting

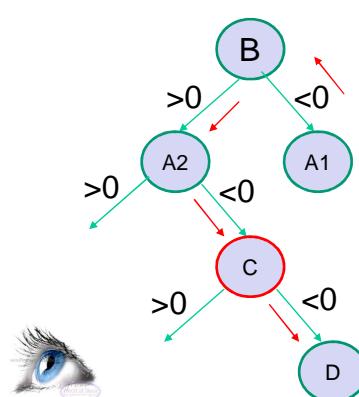
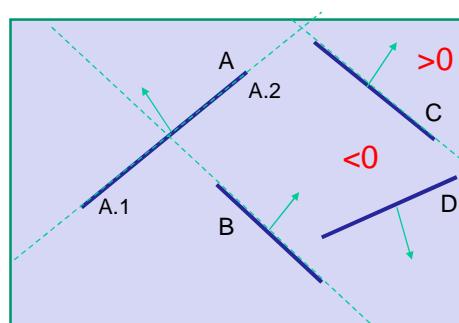
Árvore BSP em Visibilidade



Em relação a A2, o observador está no sub-espacô <0 , a ordenação, de longe para perto em relação ao observador, é na seqüência >0 , A2 e <0 . No sub-espacô <0 há 2 faces. Como ordená-las?

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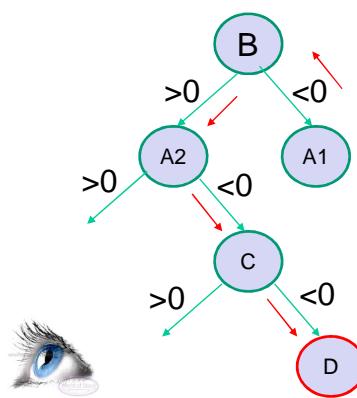
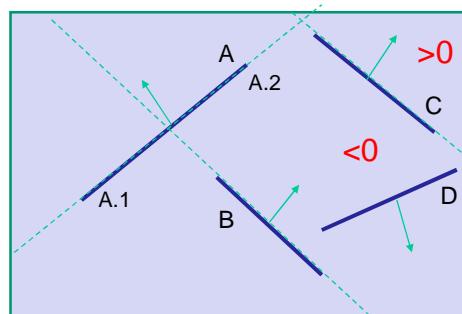
Árvore BSP em Visibilidade



... ordenando a sub-árvore de raiz C. O observador está no sub-espacô <0 em relação a C, a seqüência, de longe para perto, seria >0 , C, <0 . No sub-espacô <0 , temos uma face. A ordenação é trivial.

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EA978 – 2/2008 - Profa. Ting

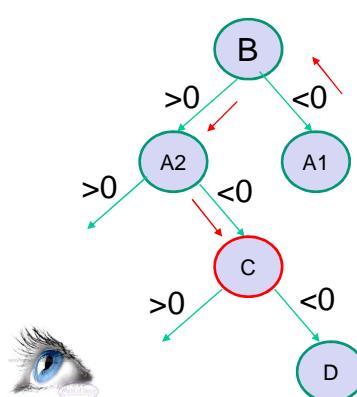
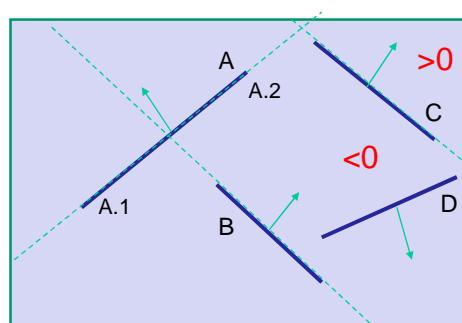
Árvore BSP em Visibilidade



A recursão pára quando alcança um folha.
A ordenação da sub-árvore com raiz C é
[C,D].

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EA978 – 2/2008 - Profa. Ting

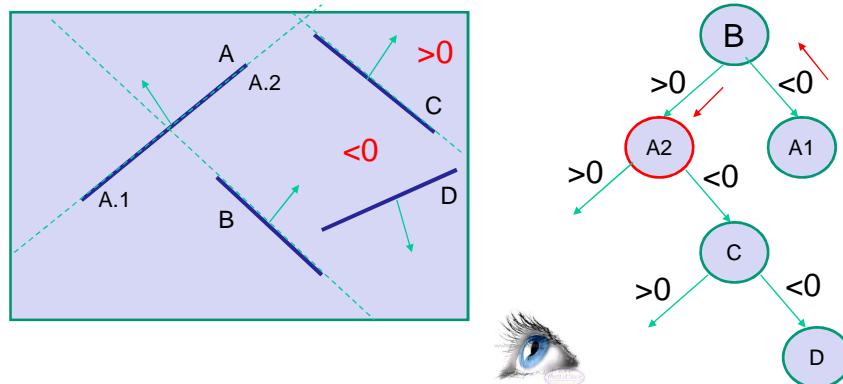
Árvore BSP em Visibilidade



A ordenação da sub-árvore com raiz A é
[A2, sub-árvore C] e a ordenação da sub-
árvore C é [C,D]. Portanto, a ordenação
das faces no sub-espacô <0 em relação a
A2 é [A2,C,D]

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EA978 – 2/2008 - Profa. Ting

Árvore BSP em Visibilidade

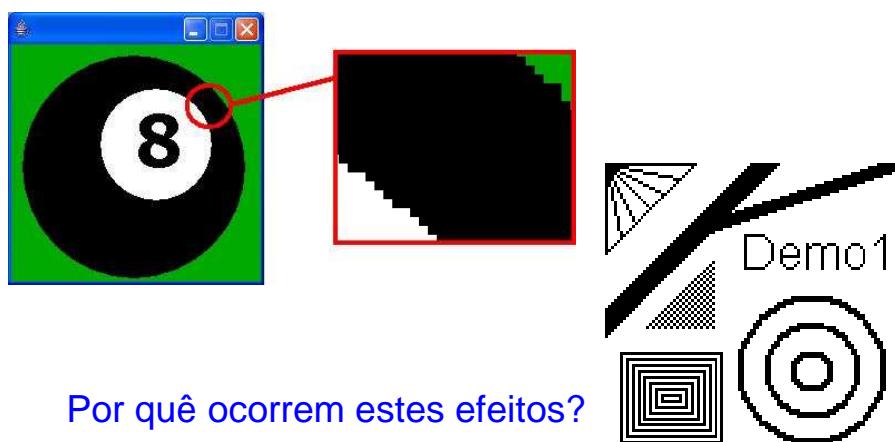


A ordenação da árvore com raiz B é [sub-árvore A1, B, sub-árvore A2]. A ordenação da sub-árvore A2 é [A2,C,D]. Portanto, a seqüência é [A1,B,A2,C,D]

IA725 – 1s2009 - Ting
EA978 – 2/2008 - Profa. Ting

Rasterização de Polígonos

Efeito de Borda Serrilhada

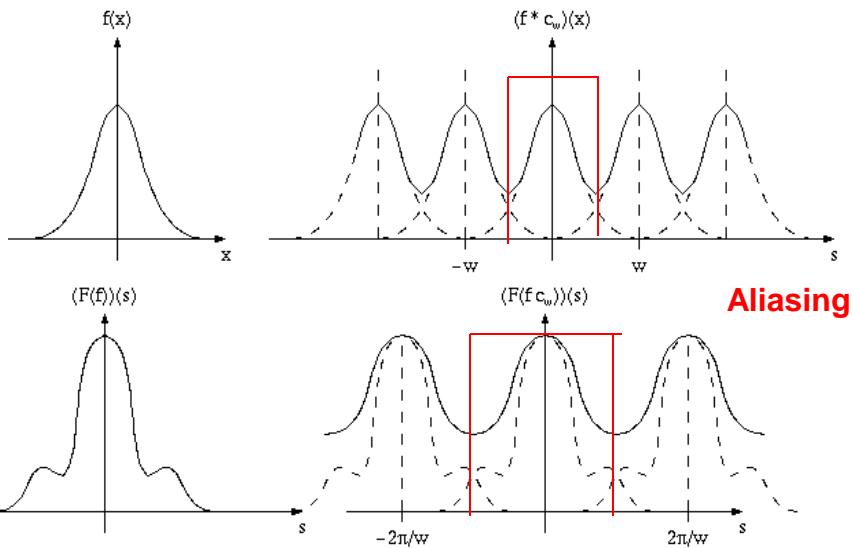


Por quê ocorrem estes efeitos?

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Amostragem 1D

Subamostragem



Rendering em Multi-passos

Motion Blur



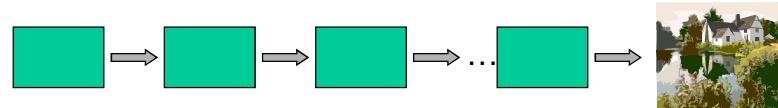
4 passos



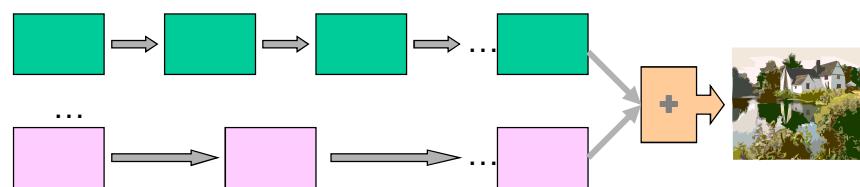
16 passos

Rendering em Multi-passos

- Rendering em um passo

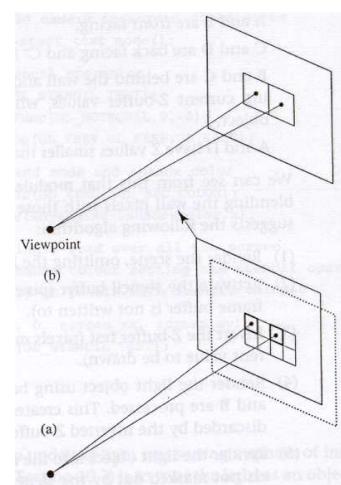
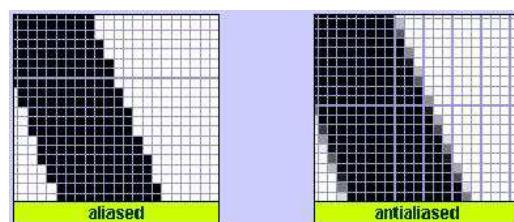


- Rendering em multi-passos



Rendering em Multi-passos

Anti-aliasing



Rendering em Multi-passos

Motion Blur



Rendering em Multi-passos

Campo de Profundidade

