Insper

Computação Gráfica

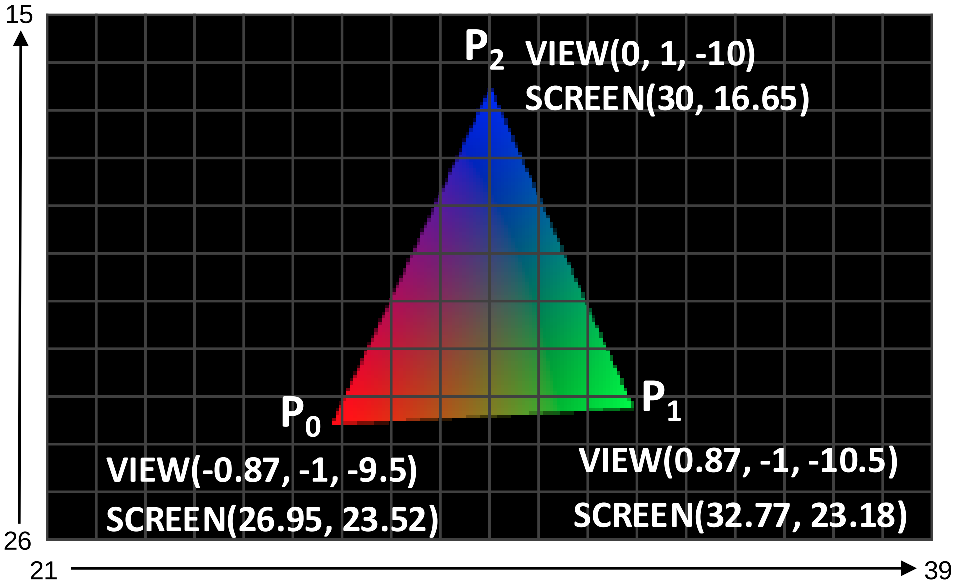
Aula 12: Revisão 2 Interpolação, MipMap, Visibilidade

Interpolação em Triângulos

Triângulo com vértices de cores diferentes

```
<Scene>
  <Viewpoint position="0 0 10"/>
  <Transform rotation="0 1 0 0.52">
    <Shape>
      <IndexedFaceSet colorPerVertex='true' coordIndex='0 1 2 -1'>
        <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
        <Color color='1 0 0 0 1 0 0 0 1'/>
      </IndexedFaceSet>
    </Shape>
  </Transform>
</Scene>
```

30°



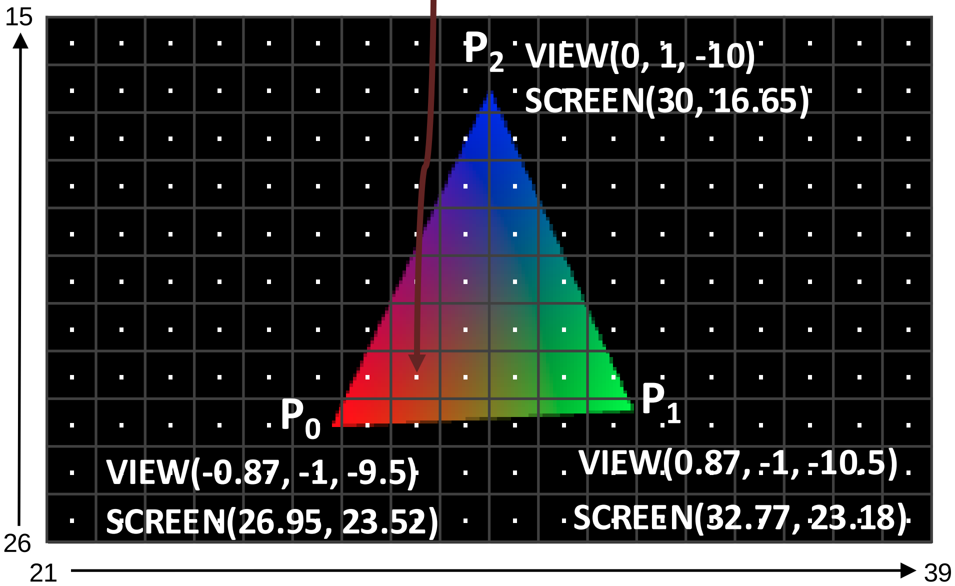
Triângulo com vértices de cores diferentes

```
<Scene>
  <Viewpoint position="0 0 10"/>
  <Transform rotation="0 1 0 0.52">
    <Shape>
      <IndexedFaceSet colorPerVertex='true' coordIndex='0 1 2 -1'>
        <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
        <Color color='1 0 0 0 1 0 0 0 1'/>
      </IndexedFaceSet>
    </Shape>
  </Transform>
</Scene>
```

30°

É triângulo?
Qual a cor?

Pixel (28, 22)



Distâncias do ponto(28, 22) as arestas

$L(x, y) = (x - x0)(y1 - y0) - (y - y0)(x1 - x0)$

centro do pixel

$L_0 = (28.5 - 32.77)(16.65 - 23.18) - (22.5 - 23.18)(30 - 32.77)$

$L_0 = (-4.27)(-6.53) - (-0.68)(-2.77)$

$L_0 = 27.8831 - 1.8836$

$\mathbf{L_0 = 25.9995}$

$L_1 = (28.5 - 30)(23.52 - 16.65) - (22.5 - 16.65)(26.95 - 30)$

$L_1 = (-1.5)(6.87) - (5.85)(-3.05)$

$L_1 = -10.305 + 17.8425$

$\mathbf{L_1 = 7.5375}$

$L_2 = (28.5 - 26.95)(23.18 - 23.52) - (22.5 - 23.52)(32.77 - 26.95)$

$L_2 = (1.55)(-0.34) - (-1.02)(5.82)$

$L_2 = -0.527 + 5.9364$

$\mathbf{L_2 = 5.4094}$

Todos positivos: Dentro !!!

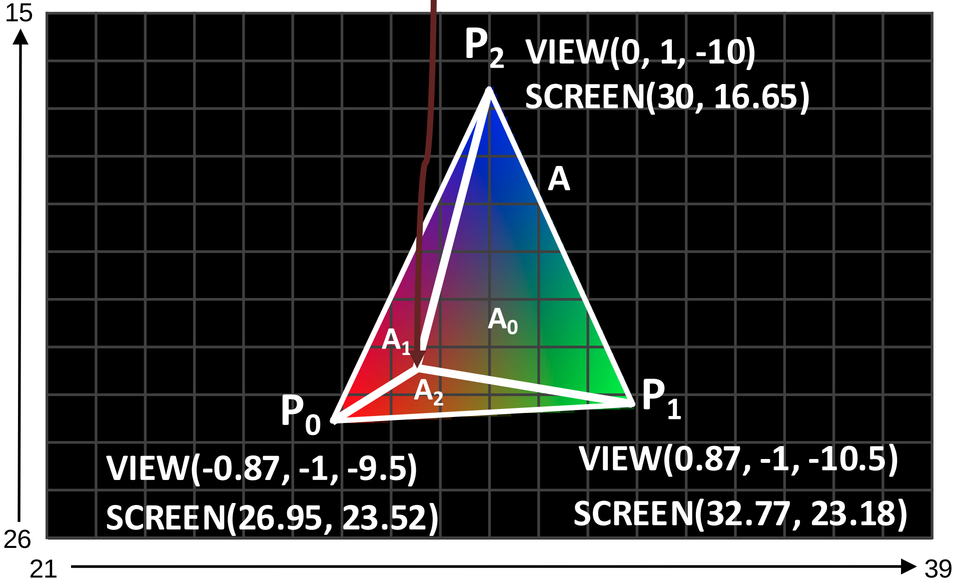
Triângulo com vértices de cores diferentes

```
<Scene>
  <Viewpoint position="0 0 10"/>
  <Transform rotation="0 1 0 0.52">
    <Shape>
      <IndexedFaceSet colorPerVertex='true' coordIndex='0 1 2 -1'>
        <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
        <Color color='1 0 0 0 1 0 0 0 1'/>
      </IndexedFaceSet>
    </Shape>
  </Transform>
</Scene>
```

30°

É triângulo?
Qual a cor?

Pixel (28, 22)



Área dos triângulos:

$Area = |x_0(y_1–y_2) + x_1(y_2–y_0) + x_2(y_0–y_1)| / 2$

A = |26.95(23.18-16.65)+32.77(16.65-23.52)+30(23.52-23.18)|/2
A = |26.95(6.53)+32.77(-6.87)+30(0.34)|/2
A = |175.9835-225.1299+10.2|/2

A = 19.4732

$A_0 = |28.5(23.18-16.65)+32.77(16.65-22.5)+30(22.5-23.18)|/2$
$A_0 = |28.5(6.53)+32.77(-5.85)+30(-0.68)|/2$
$A_0 = |186.105-191.7045-20.4|/2$

$A_0 = 12.99975$

$A_1 = |28.5(16.65-23.52)+30(23.52-22.5)+26.95(22.5-16.65)|/2$
$A_1 = |28.5(-6.87)+30(1.02)+26.95(5.85)|/2$
$A_1 = |-195.795+30.6+157.6575|/2$

$A_1 = 3.76875$

$A_2 = |28.5(23.52-23.18)+26.95(23.18-22.5)+32.77(22.5-23.52)|/2$
$A_2 = |28.5(0.34)+26.95(0.68)+32.77(-1.02)|/2$
$A_2 = |9.69+18.326-33.4254|/2$

$A_2 = 2.7047$

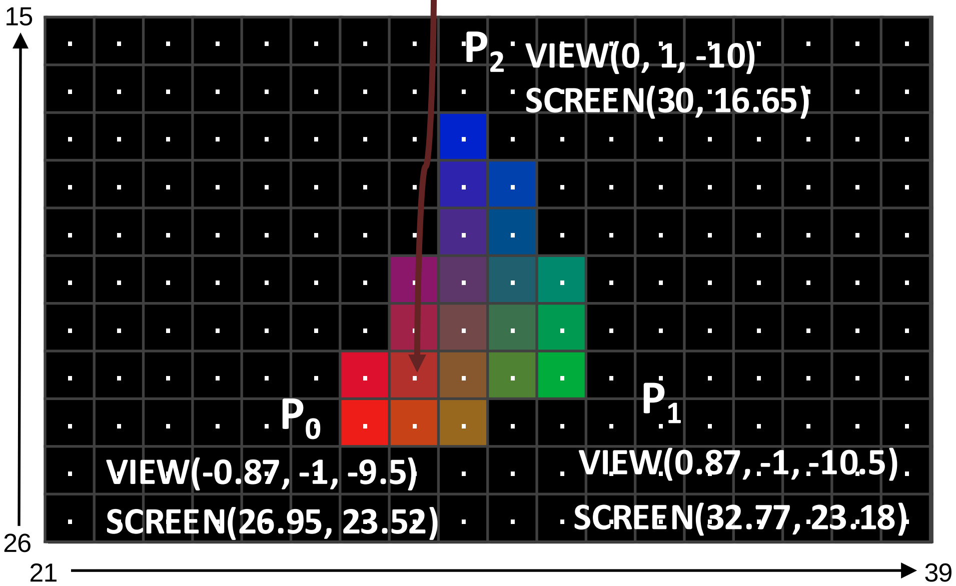
Triângulo com vértices de cores diferentes

```
<Scene>
  <Viewpoint position="0 0 10"/>
  <Transform rotation="0 1 0 0.52">
    <Shape>
      <IndexedFaceSet colorPerVertex='true' coordIndex='0 1 2 -1'>
        <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
        <Color color='1 0 0 0 1 0 0 0 1'/>
      </IndexedFaceSet>
    </Shape>
  </Transform>
</Scene>
```

30°

É triângulo?
Qual a cor?

Pixel (28, 22)



Área dos triângulos:

$A = 19.4732$

$A_0 = 12.99975$

$A_1 = 3.76875$

$A_2 = 2.7047$

Pesos

$\alpha = 12.99975 / 19.4732$ ~= 0.668

$\beta = 3.76875 / 19.4732$ ~= 0.194

$\gamma = 2.7047 / 19.4732$ ~= 0.139

ou

$\gamma = 1 - \alpha - \beta$ ~= 0.138

Cor do pixel:

$R = \alpha R_0 + \beta R_1 + \gamma R_2 = 0.668$

$G = \alpha G_0 + \beta G_1 + \gamma G_2 = 0.194$

$B = \alpha B_0 + \beta B_1 + \gamma B_2 = 0.139$

C = (0.668, 0.194, 0.139) 🟥

Percebeu que só usou coordenadas 2D da tela?

Insper

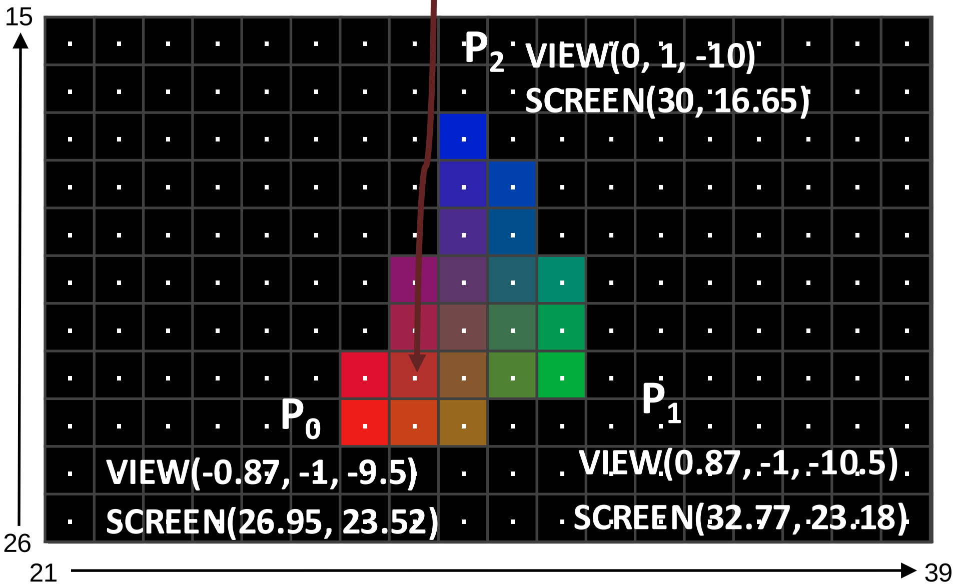
Cores do Triângulo com Correção Perspectiva

```
<Scene>
 <Viewpoint position="0 0 10"/>
 <Transform rotation="0 1 0 0.52">
  <Shape>
   <IndexedFaceSet colorPerVertex='true' coordIndex='0 1 2 -1'>
    <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
    <Color color='1 0 0 0 1 0 0 0 1'/>
   </IndexedFaceSet>
  </Shape>
 </Transform>
</Scene>
```

30°

É triângulo?
Qual a cor?

Pixel (28, 22)



Pesos

$\alpha = 0.668$

$\beta = 0.194$

$\gamma = 0.139$

$Z_0 = |-9.5| = 9.5$

$Z_1 = |-10.5| = 10.5$

$Z_2 = |-10.0| = 10$

$$Z = \frac{1}{\alpha\frac{1}{Z_0} + \beta\frac{1}{Z_1} + \gamma\frac{1}{Z_2}}$$

$$Z = \frac{1}{0.668\frac{1}{9.5} + 0.194\frac{1}{10.5} + 0.139\frac{1}{10}}$$

$$Z = \frac{1}{0.0703 + 0.0185 + 0.0139}$$

$$Z = 9.74$$

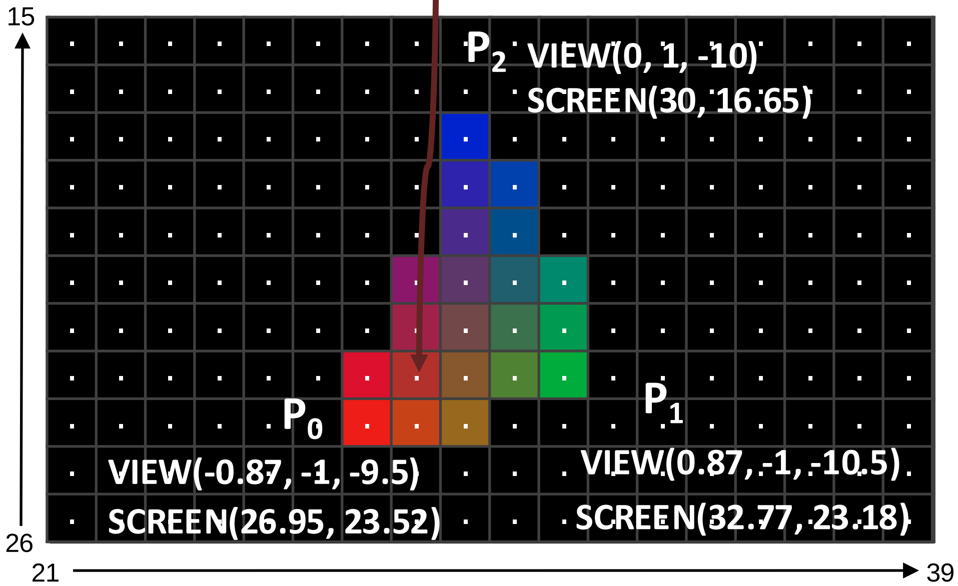
Cores do Triângulo com Correção Perspectiva

```
<Scene>
  <Viewpoint position="0 0 10"/>
  <Transform rotation="0 1 0 0.52">
    <Shape>
      <IndexedFaceSet colorPerVertex='true' coordIndex='0 1 2 -1'>
        <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
        <Color color='1 0 0 0 1 0 0 0 1'/>
      </IndexedFaceSet>
    </Shape>
  </Transform>
</Scene>
```

30°

É triângulo?
Qual a cor?

Pixel (28, 22)



Pesos

$\alpha = 0.668$

$\beta = 0.194$

$\gamma = 0.139$

Z_0 = |-9.5| = 9.5

Z_1 = |-10.5| = 10.5

Z_2 = |-10.0| = 10

$Z = 9.74$

$$C = Z \cdot \left(\alpha \frac{C_0}{Z_0} + \beta \frac{C_1}{Z_1} + \gamma \frac{C_2}{Z_2}\right)$$

$$C_R = 9.74\left(0.668\frac{1}{9.5} + 0.194\frac{0}{10.5} + 0.139\frac{0}{10}\right) = 0.685$$

$$C_G = 9.74\left(0.668\frac{0}{9.5} + 0.194\frac{1}{10.5} + 0.139\frac{0}{10}\right) = 0.180$$

$$C_B = 9.74\left(0.668\frac{0}{9.5} + 0.194\frac{0}{10.5} + 0.139\frac{1}{10}\right) = 0.135$$

C = (0.685, 0.180, 0.135) 🟥

Antes C = (0.668, 0.194, 0.139) 🟥

Obs: esses número podem variar conforme sua implementação

Aplicando Texturas

Triângulo com Texturas

```
<Scene>
  <Viewpoint position="0 0 10"/>
  <Transform rotation="0 1 0 0.52">
    <Shape>
      <IndexedFaceSet coordIndex='0 1 2 -1'>
        <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
        <TextureCoordinate point='0.0 0.0 1.0 0.0 0.5 1.0'/>
      </IndexedFaceSet>
      <Appearance>
        <ImageTexture url=' "chess.png" '/>
      </Appearance>
    </Shape>
  </Transform>
</Scene>
```

Pesos

$\alpha = 0.668$

$\beta = 0.194$

$\gamma = 0.139$

$U = \alpha U_0 + \beta U_1 + \gamma U_2$

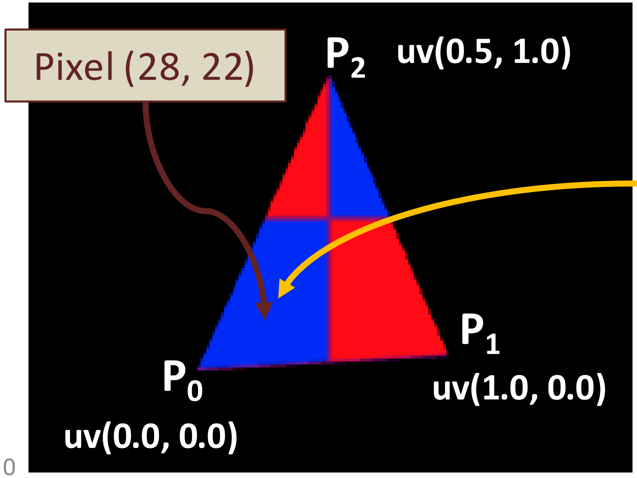
$U = 0.668*0.0 + 0.194*1.0 + 0.139*0.5$

$U = 0.2635$

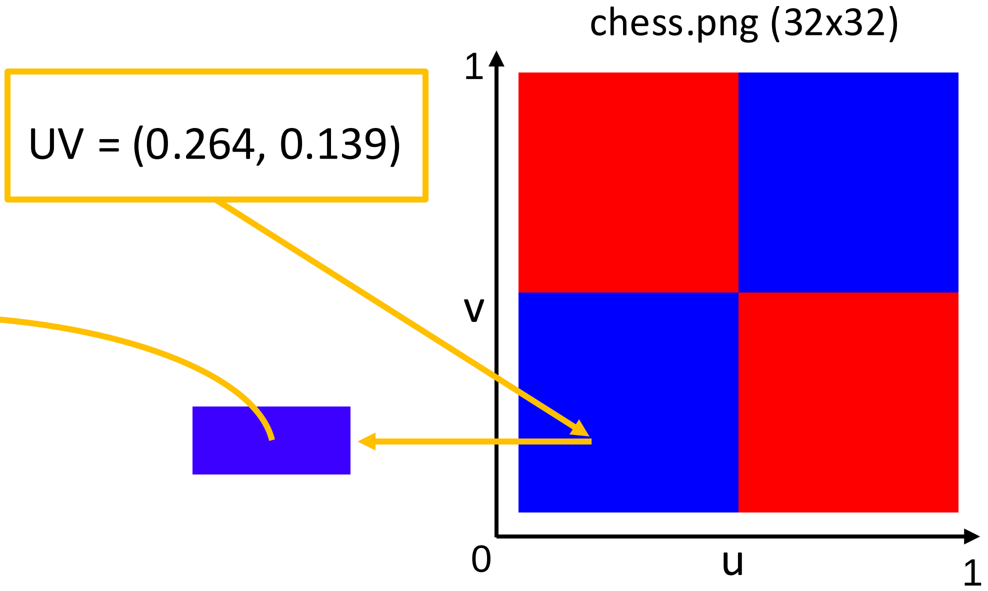
$V = \alpha V_0 + \beta V_1 + \gamma V_2$

$V = 0.668*0.0 + 0.194*0.0 + 0.139*1.0$

$V = 0.139$



Pixel (28, 22)



UV = (0.264, 0.139)

chess.png (32x32)

Triângulo com Texturas MipMap

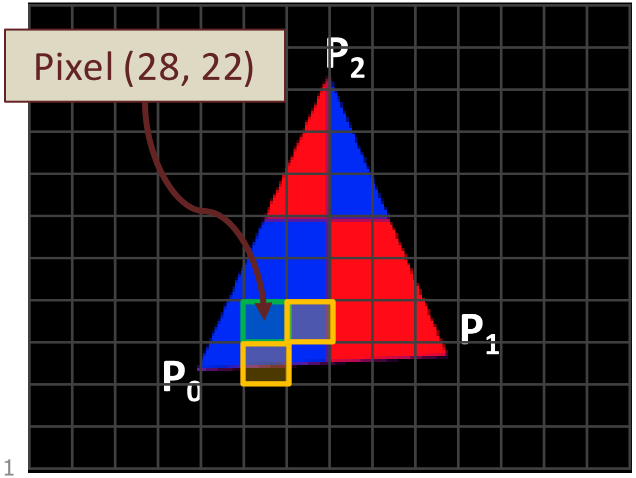
```
<Scene>
  <Viewpoint position="0 0 10"/>
  <Transform rotation="0 1 0 0.52">
    <Shape>
      <IndexedFaceSet coordIndex='0 1 2 -1'>
        <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
        <TextureCoordinate point='0.0 0.0 1.0 0.0 0.5 1.0'/>
      </IndexedFaceSet>
      <Appearance>
        <ImageTexture url=' "chess.png" '/>
      </Appearance>
    </Shape>
  </Transform>
</Scene>
```

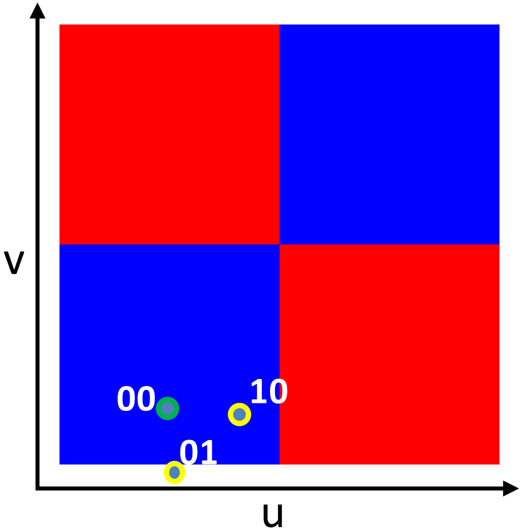
$\text{pixel}_{00}(28, 22) \Rightarrow UV(0.264, 0.139)$

Coordenadas (u,v) Vizinhas:

$\text{pixel}_{10}(29, 22) \Rightarrow UV(0.414, 0.129)$

$\text{pixel}_{01}(28, 23) \Rightarrow UV(0.248, -0.010)$





$$\frac{\partial u}{\partial x} = \frac{u_{10} - u_{00}}{x_{10} - x_{00}}$$

$$\frac{\partial u}{\partial y} = \frac{u_{01} - u_{00}}{y_{01} - y_{00}}$$

$$\frac{\partial v}{\partial x} = \frac{v_{10} - v_{00}}{x_{10} - x_{00}}$$

$$\frac{\partial v}{\partial y} = \frac{v_{01} - v_{00}}{y_{01} - y_{00}}$$

Triângulo com Texturas MipMap

U = 0.264 pixel$_{10}$(29, 22) => UV(0.414, 0.129)

V = 0.139 pixel$_{01}$(28, 23) => UV(0.248, -0.010)

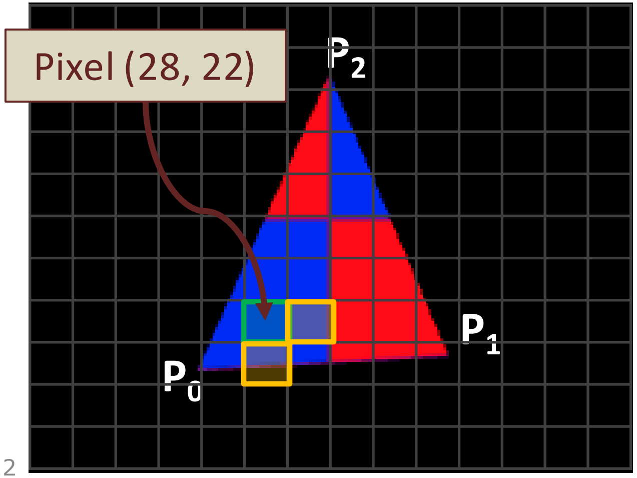
x 32

$$\frac{\partial u}{\partial x} = \frac{u_{10} - u_{00}}{29-28} = 32\left(\frac{0.414-0.264}{1}\right) = 4.8$$

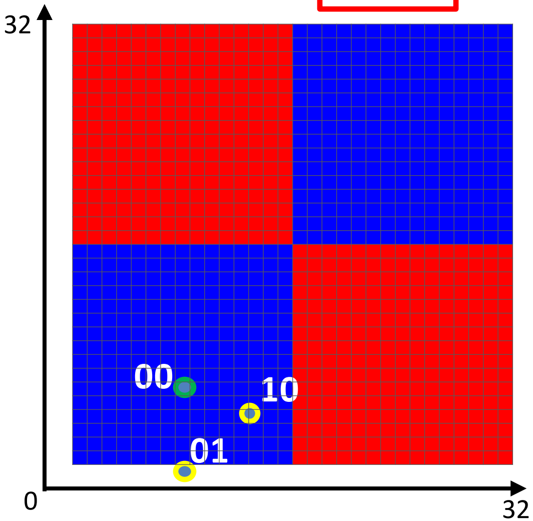
$$\frac{\partial v}{\partial x} = \frac{v_{10} - v_{00}}{29-28} = 32\left(\frac{0.129-0.139}{1}\right) = -0.32$$

$$\frac{\partial u}{\partial y} = \frac{u_{01} - u_{00}}{23-22} = 32\left(\frac{0.248-0.264}{1}\right) = -0.56$$

$$\frac{\partial v}{\partial y} = \frac{v_{01} - v_{00}}{23-22} = 32\left(\frac{-0.010-0.139}{1}\right) = -4.8$$



chess.png (32x32)



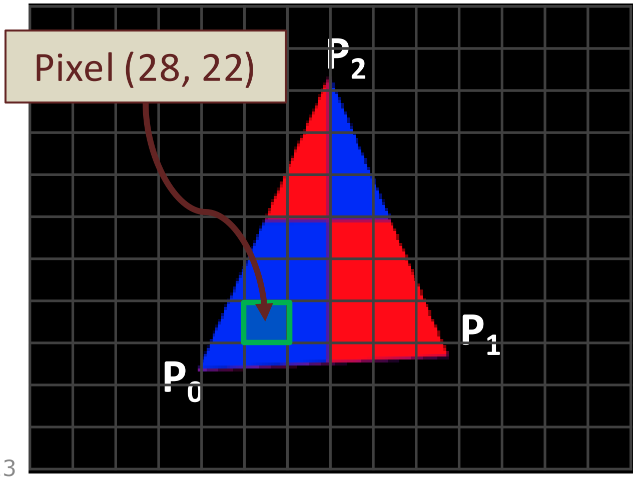
Triângulo com Texturas MipMap

U = 0.264
V = 0.139

pixel$_{10}$(29, 22) => UV(0.414, 0.129)
pixel$_{01}$(28, 23) => UV(0.248, -0.010)

$$\frac{du}{dx} = 4.8 \qquad \frac{dv}{dx} = -0.32$$

$$\frac{du}{dy} = -0.56 \qquad \frac{dv}{dy} = -4.8$$



$$D = \log_2 L$$

$$L = \max\left(\sqrt{\left(\frac{du}{dx}\right)^2 + \left(\frac{dv}{dx}\right)^2}, \sqrt{\left(\frac{du}{dy}\right)^2 + \left(\frac{dv}{dy}\right)^2}\right)$$

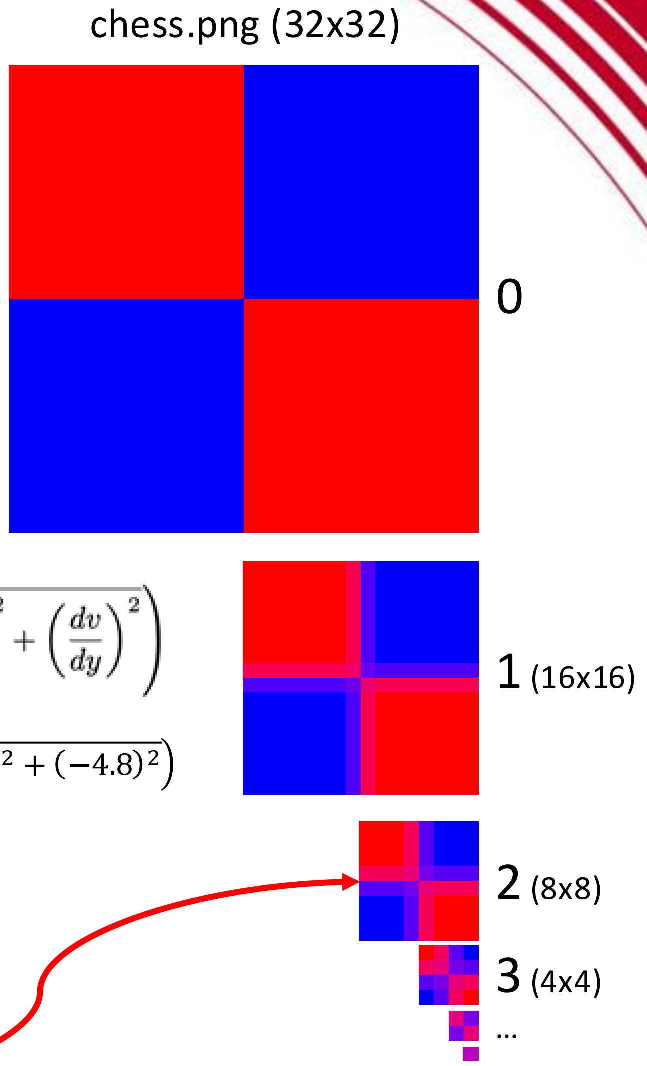
$$L = \max\left(\sqrt{(4.8)^2 + (-0.32)^2}, \sqrt{(-0.56)^2 + (-4.8)^2}\right)$$

$$L = \max(4.81, 4.83\,)$$

L = 4.83

D = 2.27

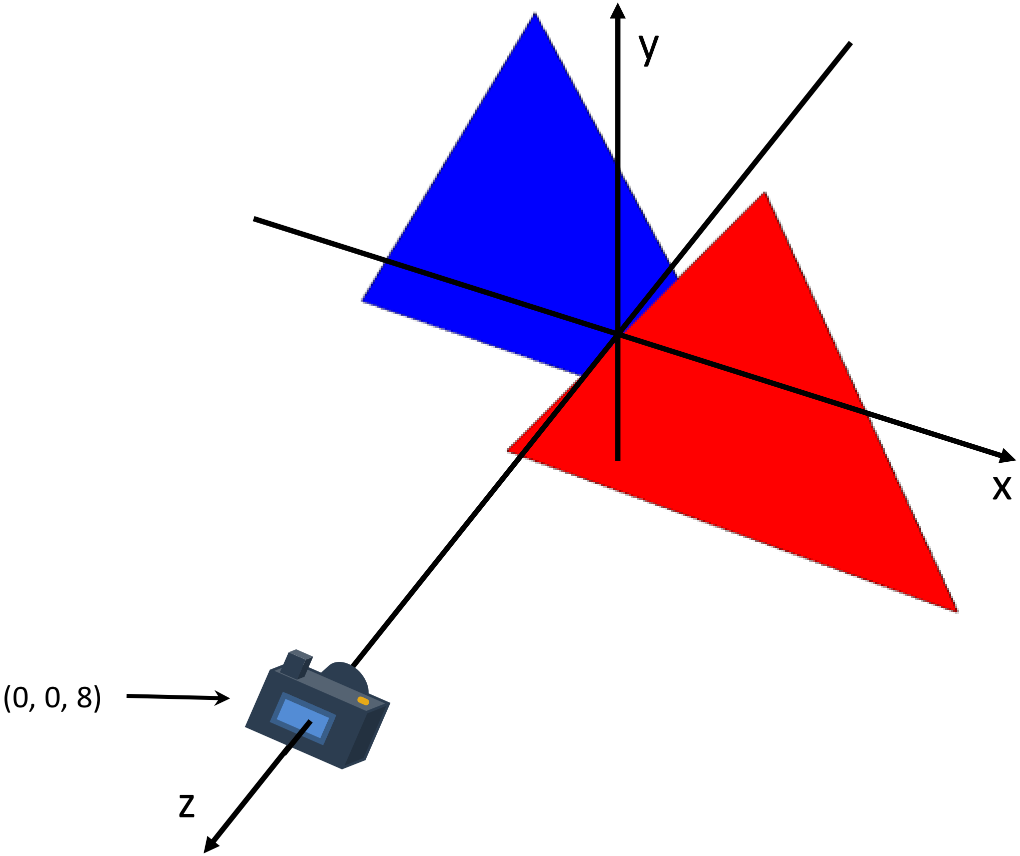
D = 2



Z-Buffer

Desenhando Dois Triângulos

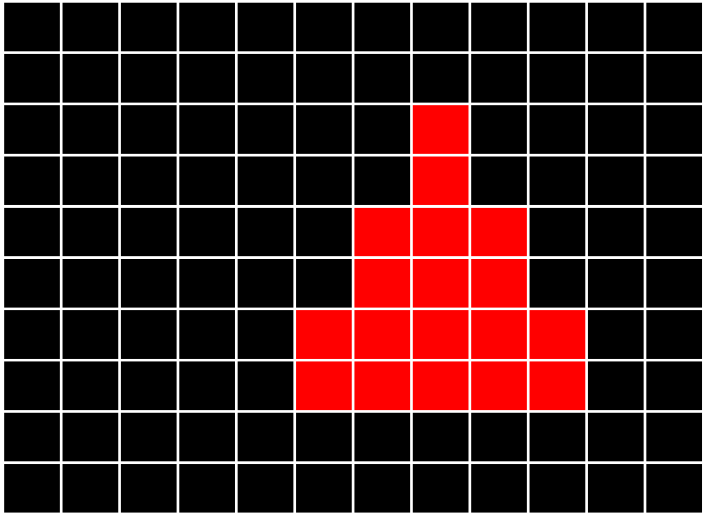
```
<Scene>
  <Viewpoint position="0 0 8">
  <Transform translation="1 0 0">
    <Shape>
      <TriangleSet>
        <Coordinate point='-2 -2 0 2 -2 0 0 2 0'/>
      </TriangleSet>
      <Appearance>
        <Material emissiveColor='1 0 0'/>
      </Appearance>
    </Shape>
  </Transform>
  <Transform translation="-1 0 0">
    <Shape>
      <TriangleSet>
        <Coordinate point='-2 -2 -1 2 -2 -1 0 2 -1'/>
      </TriangleSet>
      <Appearance>
        <Material emissiveColor='0 0 1'/>
      </Appearance>
    </Shape>
  </Transform>
</Scene>
```



Desenhando SEM Z-Buffer

```
<Scene>
  <Viewpoint position="0 0 8">
  <Transform translation="1 0 0">
    <Shape>
      <TriangleSet>
        <Coordinate point='-2 -2 0 2 -2 0 0 2 0'/>
      </TriangleSet>
      <Appearance>
        <Material emissiveColor='1 0 0'/>
      </Appearance>
    </Shape>
  </Transform>
  <Transform translation="-1 0 0">
    <Shape>
      <TriangleSet>
        <Coordinate point='-2 -2 -1 2 -2 -1 0 2 -1'/>
      </TriangleSet>
      <Appearance>
        <Material emissiveColor='0 0 1'/>
      </Appearance>
    </Shape>
  </Transform>
</Scene>
```

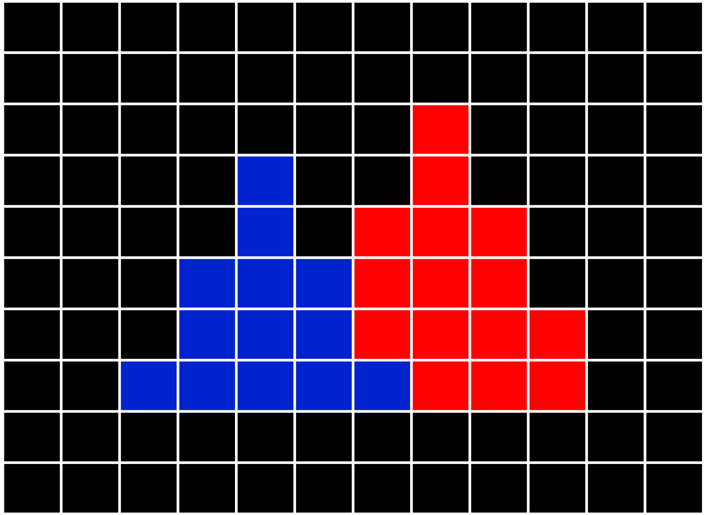
Cores



Desenhando SEM Z-Buffer

```
<Scene>
  <Viewpoint position="0 0 8">
  <Transform translation="1 0 0">
    <Shape>
      <TriangleSet>
        <Coordinate point='-2 -2 0 2 -2 0 0 2 0'/>
      </TriangleSet>
      <Appearance>
        <Material emissiveColor='1 0 0'/>
      </Appearance>
    </Shape>
  </Transform>
  <Transform translation="-1 0 0">
    <Shape>
      <TriangleSet>
        <Coordinate point='-2 -2 -1 2 -2 -1 0 2 -1'/>
      </TriangleSet>
      <Appearance>
        <Material emissiveColor='0 0 1'/>
      </Appearance>
    </Shape>
  </Transform>
</Scene>
```

Cores



Isso está Certo?

Desenhando com Z-Buffer

```xml
<Scene>
  <Viewpoint position="0 0 8">
  <Transform translation="1 0 0">
    <Shape>
      <TriangleSet>
        <Coordinate point='-2 -2 0 2 -2 0 0 2 0'/>
      </TriangleSet>
      <Appearance>
        <Material emissiveColor='1 0 0'/>
      </Appearance>
    </Shape>
  </Transform>
  <Transform translation="-1 0 0">
    <Shape>
      <TriangleSet>
        <Coordinate point='-2 -2 -1 2 -2 -1 0 2 -1'/>
      </TriangleSet>
      <Appearance>
        <Material emissiveColor='0 0 1'/>
      </Appearance>
    </Shape>
  </Transform>
</Scene>
```

Por praticidade estamos definindo o Z-buffer variando de 0 a 1.
Sendo o 1 para valores distantes e 0 para próximos da câmera.
Vamos mostrar na tabela só os dígitos que fazer diferença.

Cores

■	■	■	■	■	■	■	■	■	■	■	■
■	■	■	■	■	■	■	■	■	■	■	■
■	■	■	■	■	■	■	■	■	■	■	■
■	■	■	■	■	■	■	■	■	■	■	■
■	■	■	■	■	■	■	■	■	■	■	■
■	■	■	■	■	■	■	■	■	■	■	■
■	■	■	■	■	■	■	■	■	■	■	■
■	■	■	■	■	■	■	■	■	■	■	■
■	■	■	■	■	■	■	■	■	■	■	■
■	■	■	■	■	■	■	■	■	■	■	■

Profundidade

1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1

Desenhando com Z-Buffer

```
<Scene>
  <Viewpoint position="0 0 8">
  <Transform translation="1 0 0">
    <Shape>
      <TriangleSet>
        <Coordinate point='-2 -2 0 2 -2 0 0 2 0'/>
      </TriangleSet>
      <Appearance>
        <Material emissiveColor='1 0 0'/>
      </Appearance>
    </Shape>
  </Transform>
  <Transform translation="-1 0 0">
    <Shape>
      <TriangleSet>
        <Coordinate point='-2 -2 -1 2 -2 -1 0 2 -1'/>
      </TriangleSet>
      <Appearance>
        <Material emissiveColor='0 0 1'/>
      </Appearance>
    </Shape>
  </Transform>
</Scene>
```

```
near = 0.01 # plano de corte próximo
far = 1000  # plano de corte distante
```

Triângulo Vermelho:

- Z dos pixels no NDC ≈ 0.99751998
- Normalizando ≈ 0.99875999
- Int16 ≈ 65454
- Int32 ≈ 4289641493

Triângulo Azul:

- Z dos pixels no NDC ≈ 0.99779776
- Normalizando ≈ 0.99889888
- Int16 ≈ 65463
- Int32 ≈ 4290238020

Desenhando com Z-Buffer

```
<Scene>
  <Viewpoint position="0 0 8">
  <Transform translation="1 0 0">
    <Shape>
      <TriangleSet>
        <Coordinate point='-2 -2 0 2 -2 0 0 2 0'/>
      </TriangleSet>
      <Appearance>
        <Material emissiveColor='1 0 0'/>
      </Appearance>
    </Shape>
  </Transform>
  <Transform translation="-1 0 0">
    <Shape>
      <TriangleSet>
        <Coordinate point='-2 -2 -1 2 -2 -1 0 2 -1'/>
      </TriangleSet>
      <Appearance>
        <Material emissiveColor='0 0 1'/>
      </Appearance>
    </Shape>
  </Transform>
</Scene>
```

```
near = 5 # plano de corte próximo
far = 10 # plano de corte distante
```

Triângulo Vermelho:

- Z dos pixels no NDC = 0.5
- Normalizando = 0.75 ≈ **0.8**
- Int16 ≈ 49151
- Int32 ≈ 3221225471

Triângulo Azul:

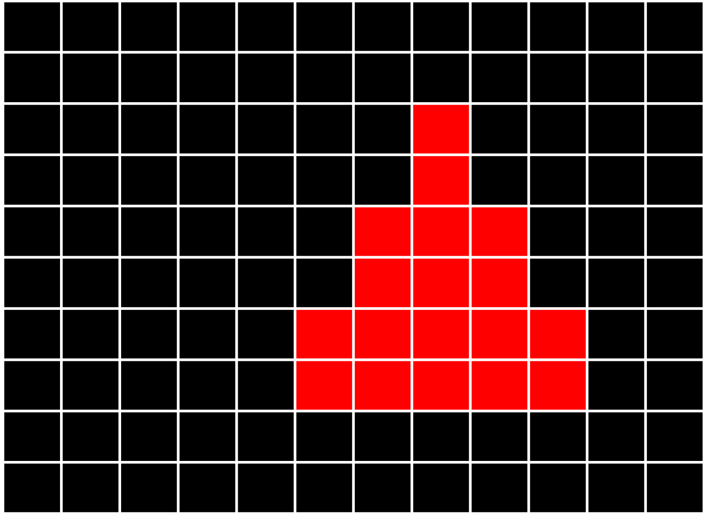
- Z dos pixels no NDC ≈ 0.77777778
- Normalizando = 0.88888888 ≈ **0.9**
- Int16 ≈ 58253
- Int32 ≈ 3817748707

Desenhando com Z-Buffer

```
<Scene>
  <Viewpoint position="0 0 8">
  <Transform translation="1 0 0">
    <Shape>
      <TriangleSet>
        <Coordinate point='-2 -2 0 2 -2 0 0 2 0'/>
      </TriangleSet>
      <Appearance>
        <Material emissiveColor='1 0 0'/>
      </Appearance>
    </Shape>
  </Transform>
  <Transform translation="-1 0 0">
    <Shape>
      <TriangleSet>
        <Coordinate point='-2 -2 -1 2 -2 -1 0 2 -1'/>
      </TriangleSet>
      <Appearance>
        <Material emissiveColor='0 0 1'/>
      </Appearance>
    </Shape>
  </Transform>
</Scene>
```

Por praticidade estamos definindo o Z-buffer variando de 0 a 1.
Sendo o 1 para valores distantes e 0 para próximos da câmera.

Cores



Profundidade (near = 5, far = 10)

1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	.8	1	1	1	1
1	1	1	1	1	1	1	.8	1	1	1	1
1	1	1	1	1	1	.8	.8	.8	1	1	1
1	1	1	1	1	1	.8	.8	.8	1	1	1
1	1	1	1	1	.8	.8	.8	.8	.8	1	1
1	1	1	1	1	.8	.8	.8	.8	.8	1	1
1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1

Desenhando com Z-Buffer

```
<Scene>
  <Viewpoint position="0 0 8">
  <Transform translation="1 0 0">
    <Shape>
      <TriangleSet>
        <Coordinate point='-2 -2 0 2 -2 0 0 2 0'/>
      </TriangleSet>
      <Appearance>
        <Material emissiveColor='1 0 0'/>
      </Appearance>
    </Shape>
  </Transform>
  <Transform translation="-1 0 0">
    <Shape>
      <TriangleSet>
        <Coordinate point='-2 -2 -1 2 -2 -1 0 2 -1'/>
      </TriangleSet>
      <Appearance>
        <Material emissiveColor='0 0 1'/>
      </Appearance>
    </Shape>
  </Transform>
</Scene>
```

Cores

⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛
⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛
⬛	⬛	⬛	⬛	⬛	⬛	⬛	🟥	⬛	⬛	⬛	⬛
⬛	⬛	⬛	⬛	🟦	⬛	⬛	🟥	⬛	⬛	⬛	⬛
⬛	⬛	⬛	⬛	🟦	⬛	🟥	🟥	🟥	⬛	⬛	⬛
⬛	⬛	⬛	🟦	🟦	🟦	🟥	🟥	🟥	⬛	⬛	⬛
⬛	⬛	⬛	🟦	🟦	🟥	🟥	🟥	🟥	🟥	⬛	⬛
⬛	⬛	🟦	🟦	🟦	🟥	🟥	🟥	🟥	🟥	⬛	⬛
⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛
⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛

Profundidade (near = 5, far = 10)

1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	.8	1	1	1	1
1	1	1	1	.9	1	1	.8	1	1	1	1
1	1	1	1	.9	1	.8	.8	.8	1	1	1
1	1	1	.9	.9	.9	.8	.8	.8	1	1	1
1	1	1	.9	.9	.8	.8	.8	.8	.8	1	1
1	1	.9	.9	.9	.8	.8	.8	.8	.8	1	1
1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1

Nesses pixels o triângulo azul estava atrás do vermelho, logo os valores não mudaram e o triângulo vermelho permaneceu.

Transparência

Transparência

```
<Scene>
  <Viewpoint position="0 0 8">
  <Transform translation="-1 0 0">
    <Shape>
      <TriangleSet>
        <Coordinate point='-2 -2 -1 2 -2 -1 0 2 -1'/>
      </TriangleSet>
      <Appearance>
        <Material emissiveColor ='0 0 1'/>
      </Appearance>
    </Shape>
  </Transform>
  <Transform translation="1 0 0">
    <Shape>
      <TriangleSet>
        <Coordinate point='-2 -2 0 2 -2 0 0 2 0'/>
      </TriangleSet>
      <Appearance>
        <Material emissiveColor=‘0 1 0’
                  transparency=‘0.4’/>
      </Appearance>
    </Shape>
  </Transform>
</Scene>
```

Vamos deixar o triângulo transparente como último no processo para evitar ter de ordenar os triângulos.

Transparência

```
<Scene>
  <Viewpoint position="0 0 8">
  <Transform translation="1 0 0">
    <Shape>
      <TriangleSet>
        <Coordinate point='-2 -2 -1 2 -2 -1 0 2 -1'/>
      </TriangleSet>
      <Appearance>
        <Material emissiveColor ='0 0 1'/>
      </Appearance>
    </Shape>
  </Transform>
  <Transform translation="-1 0 0">
    <Shape>
      <TriangleSet>
        <Coordinate point='-2 -2 0 2 -2 0 0 2 0'/>
      </TriangleSet>
      <Appearance>
        <Material emissiveColor="0 1 0"
                       transparency="0.4"/>
      </Appearance>
    </Shape>
  </Transform>
</Scene>
```

Cores (Vermelho, Verde, Azul)

(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)
(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)
(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)
(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,1)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)
(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,1)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)
(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,1)	(0,0,1)	(0,0,1)	(0,0,0)	(0,0,0)	(0,0,0)
(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,1)	(0,0,1)	(0,0,1)	(0,0,0)	(0,0,0)	(0,0,0)
(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,1)	(0,0,1)	(0,0,1)	(0,0,1)	(0,0,1)	(0,0,0)	(0,0,0)
(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)
(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)

```
cor_anterior = framebuffer[x,y] * transparência
cor_nova = rbg * (1 – transparência)
framebuffer[x,y] = cor_anterior + cor_nova
```

Transparência

```
<Scene>
  <Viewpoint position="0 0 8">
  <Transform translation="1 0 0">
    <Shape>
      <TriangleSet>
        <Coordinate point='-2 -2 -1 2 -2 -1 0 2 -1'/>
      </TriangleSet>
      <Appearance>
        <Material emissiveColor ='0 0 1'/>
      </Appearance>
    </Shape>
  </Transform>
  <Transform translation="-1 0 0">
    <Shape>
      <TriangleSet>
        <Coordinate point='-2 -2 0 2 -2 0 0 2 0'/>
      </TriangleSet>
      <Appearance>
        <Material emissiveColor="0 1 0"
                        transparency="0.4"/>
      </Appearance>
    </Shape>
  </Transform>
</Scene>
```

Cores (Vermelho, Verde, Azul)

(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)
(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)
(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0.6,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)
(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0.6,0)	(0,0,0)	(0,0,0)	(0,0,1)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)
(0,0,0)	(0,0,0)	(0,0,0)	(0,0.6,0)	(0,0.6,0)	(0,0.6,0)	(0,0,0)	(0,0,1)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)
(0,0,0)	(0,0,0)	(0,0,0)	(0,0.6,0)	(0,0.6,0)	(0,0.6,0)	(0,0,1)	(0,0,1)	(0,0,1)	(0,0,0)	(0,0,0)	(0,0,0)
(0,0,0)	(0,0,0)	(0,0.6,0)	(0,0.6,0)	(0,0.6,0)	(0,0.6,0)	(0,0.6,0.4)	(0,0,1)	(0,0,1)	(0,0,0)	(0,0,0)	(0,0,0)
(0,0,0)	(0,0,0)	(0,0.6,0)	(0,0.6,0)	(0,0.6,0)	(0,0.6,0.4)	(0,0.6,0.4)	(0,0,1)	(0,0,1)	(0,0,1)	(0,0,0)	(0,0,0)
(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)
(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)	(0,0,0)

```
cor_anterior = framebuffer[x,y] * transparência
cor_nova = rbg * (1 – transparência)
framebuffer[x,y] = cor_anterior + cor_nova
```

Computação Gráfica

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