

Computação Gráfica

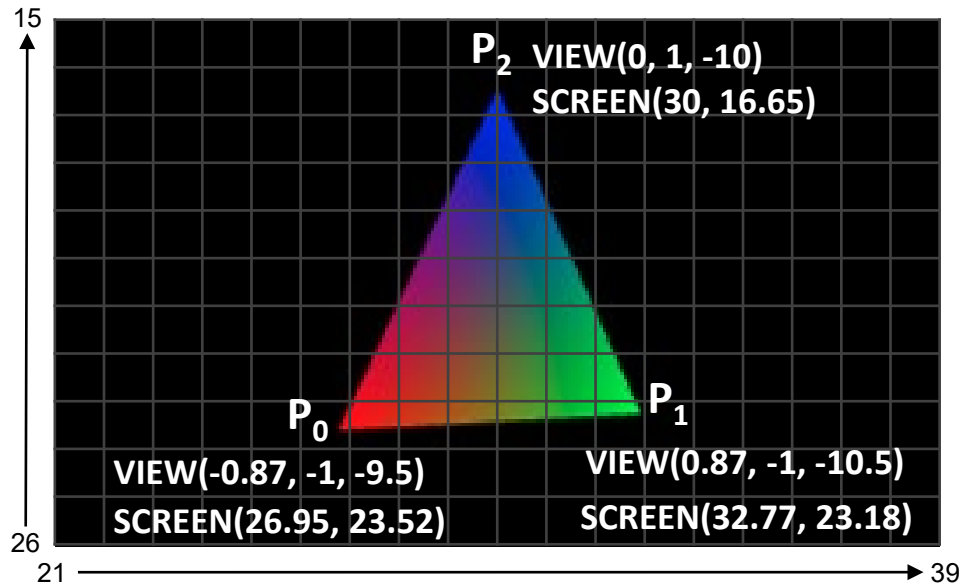
Aula 12: Revisão 2 Interpolação, MipMap, Visibilidade

Interpolação em Triângulos



Triângulo com vértices de cores diferentes

```
<Scene>
  <Viewpoint position="0 0 10"/>
  <Transform rotation="0 1 0 0.52"> ← 30°
    <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>
```

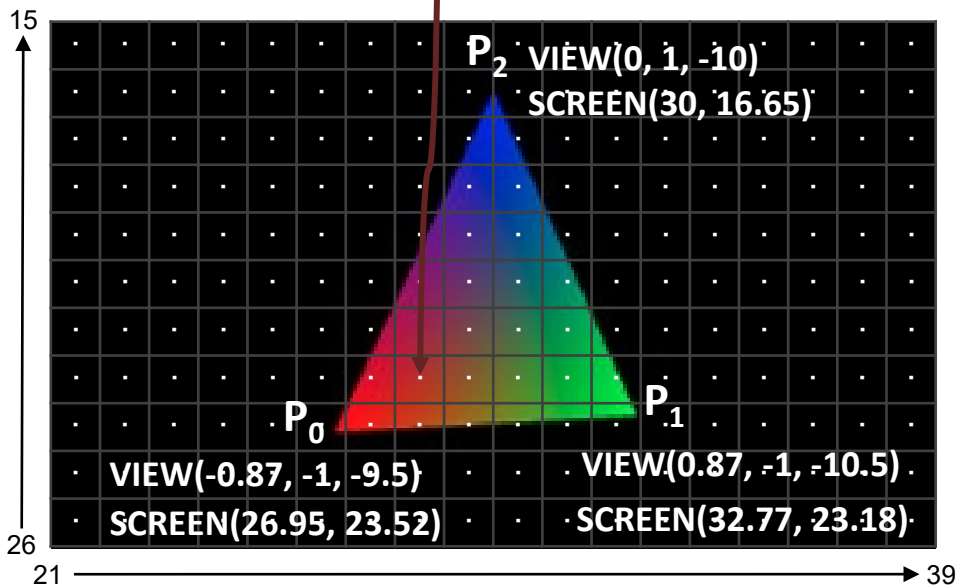


Triângulo com vértices de cores diferentes

```
<Scene>
  <Viewpoint position="0 0 10"/>
  <Transform rotation="0 1 0 0.52"> ← 30°
    <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>
```

Pixel (28, 22)

É triângulo?
Qual a cor?



Distâncias do ponto(28, 22) as arestas

$$L(x, y) = (x - x_0)(y_1 - y_0) - (y - y_0)(x_1 - x_0)$$

centro do pixel

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

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

$$L_0 = 27.8831 - 1.8836$$

$$L_0 = 25.9995$$

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

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

$$L_1 = -10.305 + 17.8425$$

$$L_1 = 7.5375$$

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

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

$$L_2 = -0.527 + 5.9364$$

$$L_2 = 5.4094$$

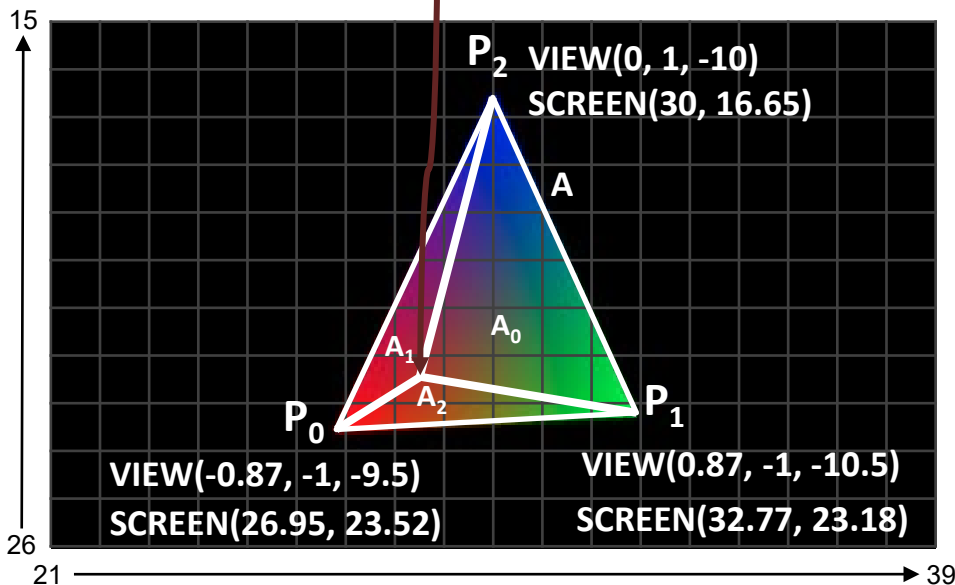
Todos positivos: Dentro !!!

Triângulo com vértices de cores diferentes

```
<Scene>
  <Viewpoint position="0 0 10"/>
  <Transform rotation="0 1 0 0.52"> ← 30°
    <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>
```

Pixel (28, 22)

É triângulo?
Qual a cor?



Área dos triângulos:

$$\text{Area} = |x_0(y_1 - y_2) + x_1(y_2 - y_0) + x_2(y_0 - y_1)| / 2$$

$$A = |26.95(23.18 - 16.65) + 32.77(16.65 - 23.52) + 30(23.52 - 23.18)| / 2$$

$$A = |26.95(6.53) + 32.77(-6.87) + 30(0.34)| / 2$$

$$A = |175.9835 - 225.1299 + 10.2| / 2$$

$$\mathbf{A = 19.4732}$$

$$A_0 = |28.5(23.18 - 16.65) + 32.77(16.65 - 22.5) + 30(22.5 - 23.18)| / 2$$

$$A_0 = |28.5(6.53) + 32.77(-5.85) + 30(-0.68)| / 2$$

$$A_0 = |186.105 - 191.7045 - 20.4| / 2$$

$$\mathbf{A_0 = 12.99975}$$

$$A_1 = |28.5(16.65 - 23.52) + 30(23.52 - 22.5) + 26.95(22.5 - 16.65)| / 2$$

$$A_1 = |28.5(-6.87) + 30(1.02) + 26.95(5.85)| / 2$$

$$A_1 = |-195.795 + 30.6 + 157.6575| / 2$$

$$\mathbf{A_1 = 3.76875}$$

$$A_2 = |28.5(23.52 - 23.18) + 26.95(23.18 - 22.5) + 32.77(22.5 - 23.52)| / 2$$

$$A_2 = |28.5(0.34) + 26.95(0.68) + 32.77(-1.02)| / 2$$

$$A_2 = |9.69 + 18.326 - 33.4254| / 2$$

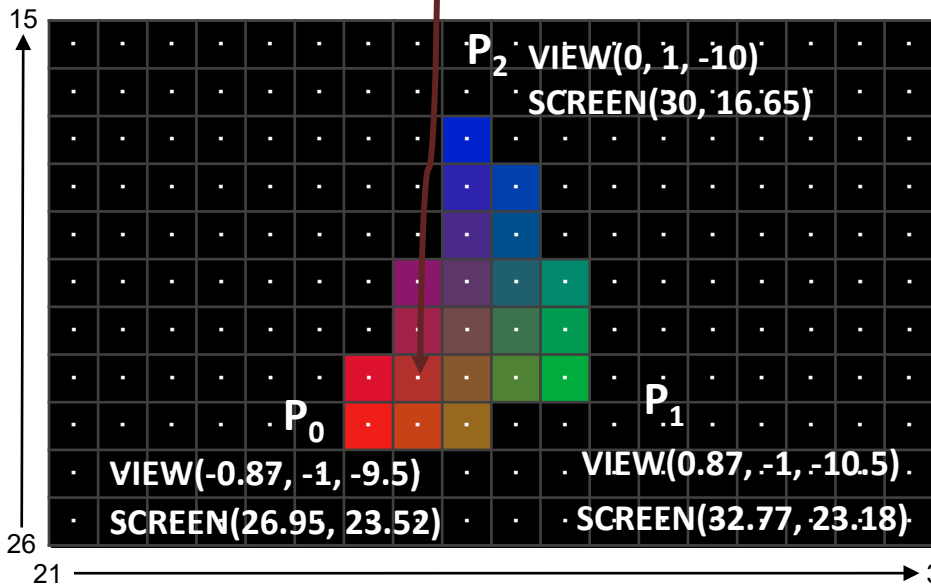
$$\mathbf{A_2 = 2.7047}$$

Triângulo com vértices de cores diferentes

```
<Scene>
  <Viewpoint position="0 0 10"/>
  <Transform rotation="0 1 0 0.52"> ← 30°
    <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>
```

Pixel (28, 22)

É triângulo?
Qual a cor?



Área dos triângulos:

$A = 19.4732$

$A_0 = 12.99975$

$A_1 = 3.76875$

$A_2 = 2.7047$

Pesos

$\alpha = 12.99975 / 19.4732 \approx 0.668$

$\beta = 3.76875 / 19.4732 \approx 0.194$

$\gamma = 2.7047 / 19.4732 \approx 0.139$

ou

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

Cor do pixel:

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

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

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

$C = (0.668, 0.194, 0.139)$

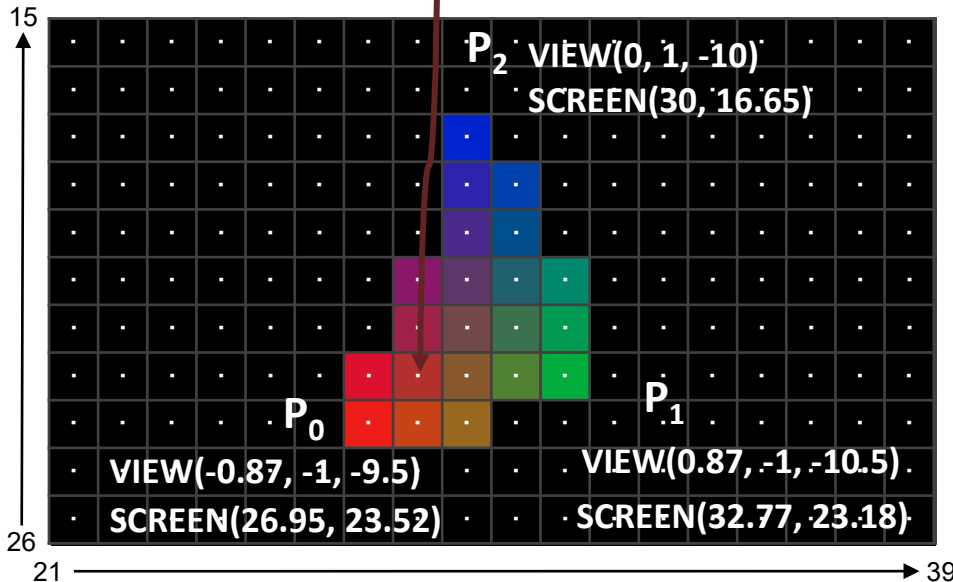
Percebeu que só usou coordenadas 2D da tela? 

Cores do Triângulo com Correção Perspectiva

```
<Scene>
  <Viewpoint position="0 0 10"/>
  <Transform rotation="0 1 0 0.52"> ← 30°
    <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>
```

Pixel (28, 22)

É triângulo?
Qual a cor?



Pesos

$\alpha = 0.668$

$\beta = 0.194$

$\gamma = 0.139$

$Z_0 = |-9.5| = 9.5$

$Z_1 = |-10.5| = 10.5$

$Z_2 = |-10.0| = 10$

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

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

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

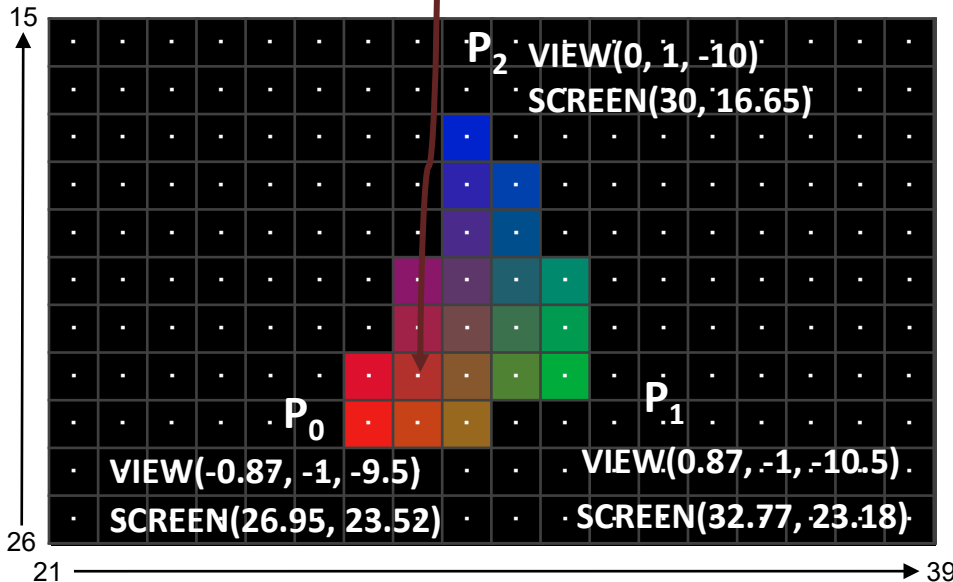
$$Z = 9.74$$

Cores do Triângulo com Correção Perspectiva

```
<Scene>
  <Viewpoint position="0 0 10"/>
  <Transform rotation="0 1 0 0.52"> ← 30°
    <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>
```

Pixel (28, 22)

É triângulo?
Qual a cor?



Pesos
 $\alpha = 0.668$
 $\beta = 0.194$
 $\gamma = 0.139$

$Z_0 = |-9.5| = 9.5$
 $Z_1 = |-10.5| = 10.5$
 $Z_2 = |-10.0| = 10$
 $Z = 9.74$

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

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

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

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

$C = (0.685, 0.180, 0.135)$

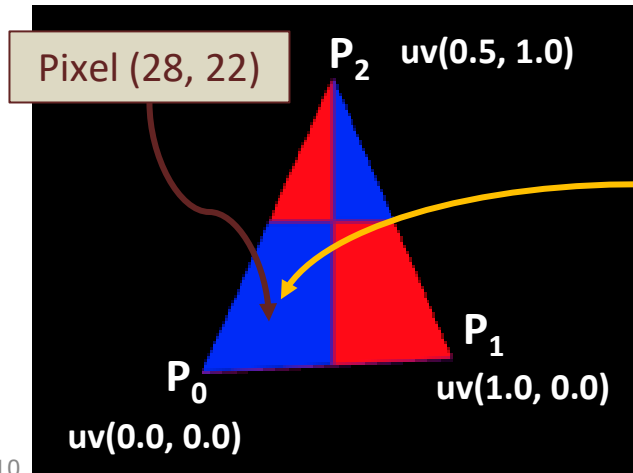
Antes $C = (0.668, 0.194, 0.139)$

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

$$\alpha = 0.668$$

$$\beta = 0.194$$

$$\gamma = 0.139$$

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

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

$$U = 0.2635$$

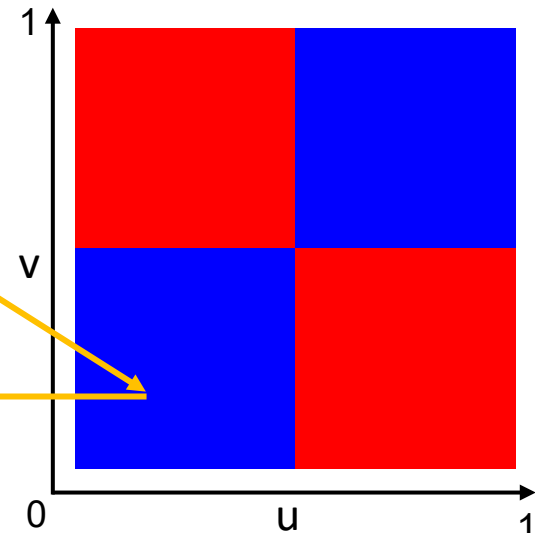
$$V = \alpha V_0 + \beta V_1 + \gamma V_2$$

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

$$V = 0.139$$

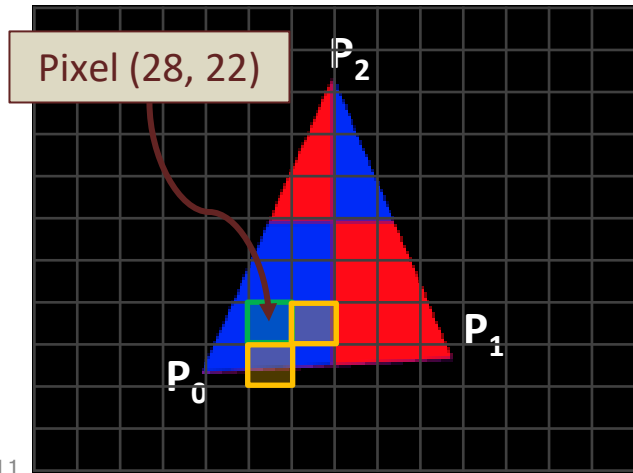
$$UV = (0.264, 0.139)$$

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>
```



pixel₀₀(28, 22) => UV(0.264, 0.139)

Coordenadas (u,v) Vizinhas:

pixel₁₀(29, 22) => UV(0.414, 0.129)

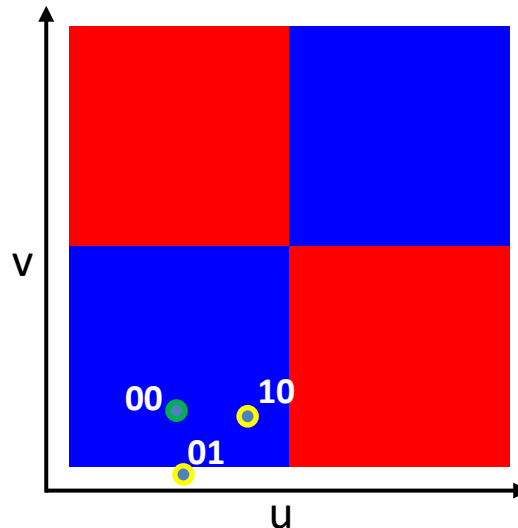
pixel₀₁(28, 23) => UV(0.248, -0.010)

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

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

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

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



Triângulo com Texturas MipMap

$$U = 0.264 \quad \text{pixel}_{10}(29, 22) \Rightarrow UV(0.414, 0.129)$$

$$V = 0.139 \quad \text{pixel}_{01}(28, 23) \Rightarrow UV(0.248, -0.010)$$

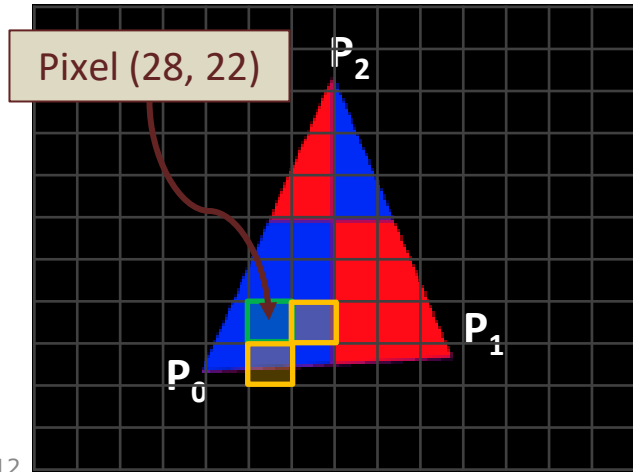
x 32

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

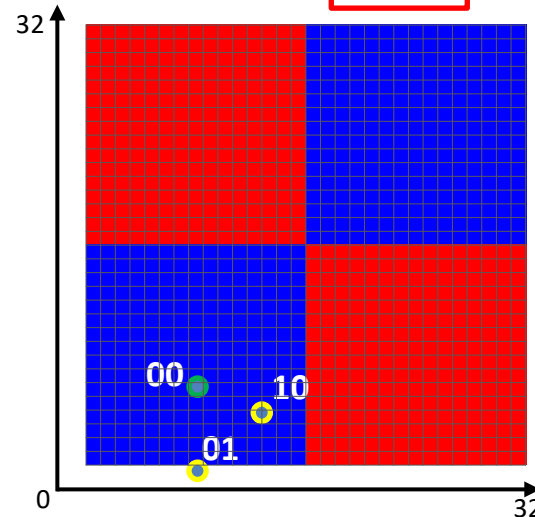
$$\frac{\partial v}{\partial x} = \frac{v_{10} - v_{00}}{29 - 28} = 32 \left(\frac{0.129 - 0.139}{1} \right) = -0.32$$

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

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



chess.png (32x32)



Triângulo com Texturas MipMap

$$U = 0.264$$

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

$$V = 0.139$$

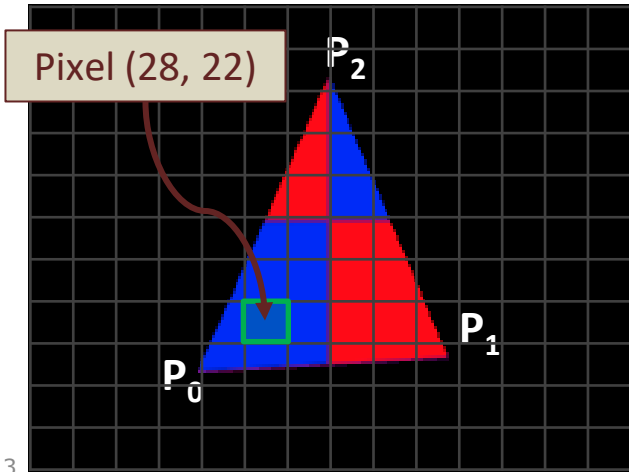
$$\text{pixel}_{01}(28, 23) \Rightarrow UV(0.248, -0.010)$$

$$\frac{du}{dx} = 4.8$$

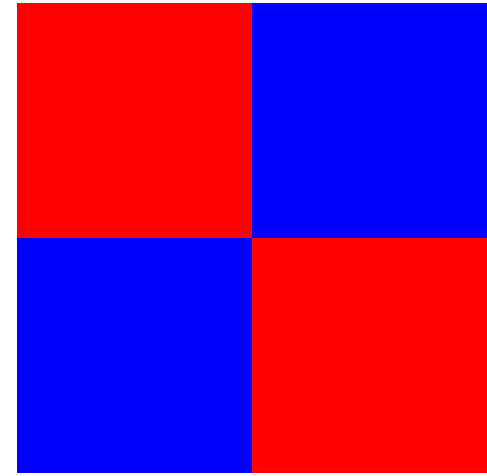
$$\frac{dv}{dx} = -0.32$$

$$\frac{du}{dy} = -0.56$$

$$\frac{dv}{dy} = -4.8$$



chess.png (32x32)



0

$$D = \log_2 L$$

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

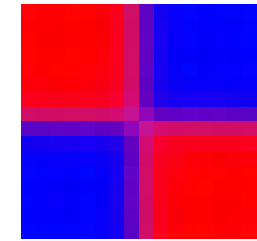
$$L = \max \left(\sqrt{(4.8)^2 + (-0.32)^2}, \sqrt{(-0.56)^2 + (-4.8)^2} \right)$$

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

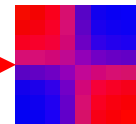
$$L = 4.83$$

$$D = 2.27$$

$$D = 2$$



1 (16x16)



2 (8x8)



3 (4x4)

...

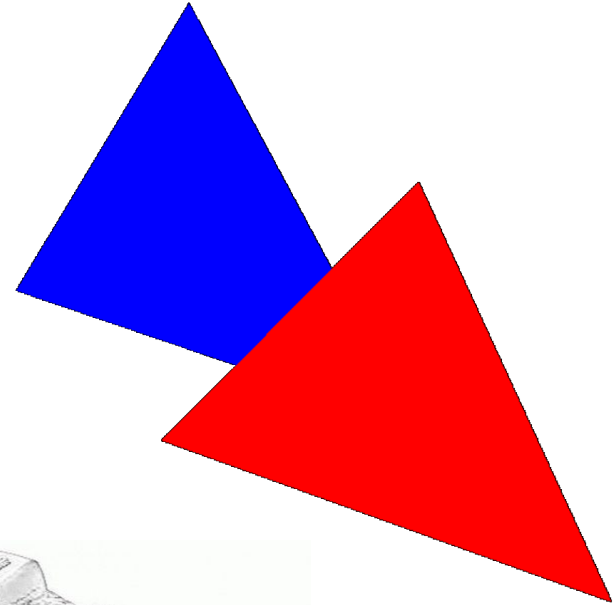
Insper

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>
  </Viewpoint>
</Scene>
```

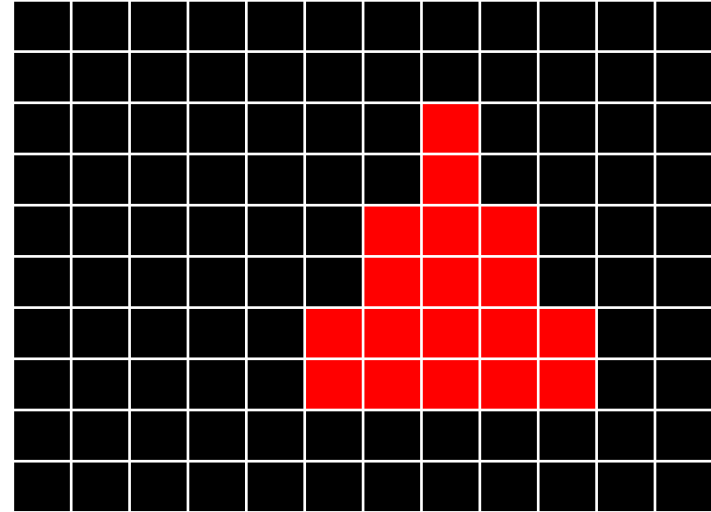


Desenhando SEM Z-Buffer

```
<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>
```



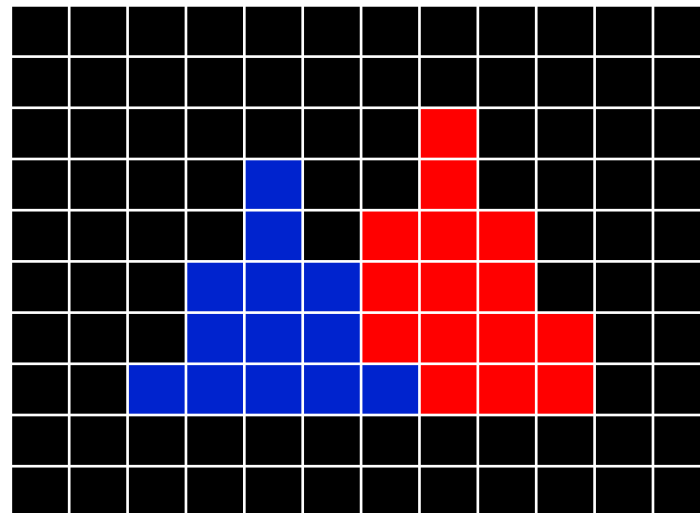
Cores



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



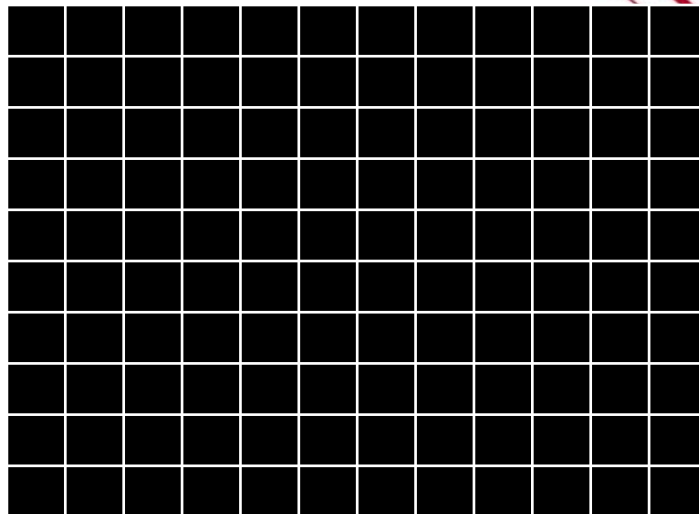
Isso está Certo?

Desenhando com Z-Buffer

```
<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
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

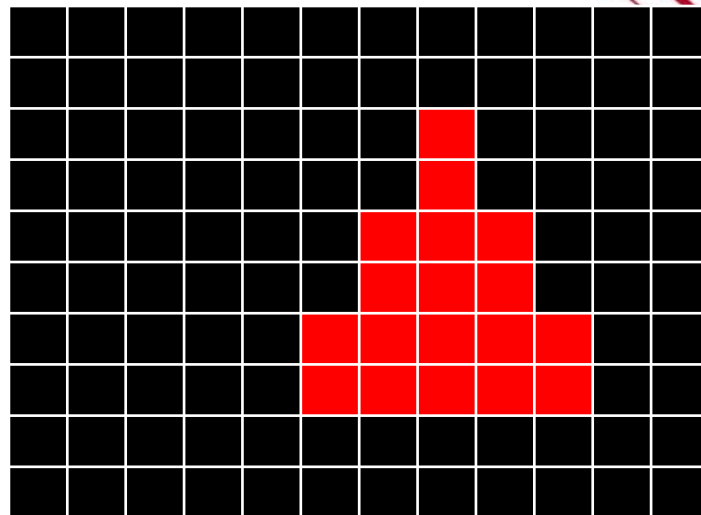
```
<Scene>
  <Viewpoint position="0 0 8">
    <Transform translation="1 0 0">
      <Shape>
        <TriangleSet>
          <Coordinate point='-2 -2 0 2 -2 0 0 2 0' />
        </TriangleSet>
        <Appearance>
          <Material emissiveColor='1 0 0' />
        </Appearance>
      </Shape>
    </Transform>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

Z no NDC
0.99751998

Normalizando
0.99875999

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 (0.998X)

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	.7	1	1	1	1
1	1	1	1	1	1	1	.7	1	1	1	1
1	1	1	1	1	1	.7	.7	.7	1	1	1
1	1	1	1	1	1	.7	.7	.7	1	1	1
1	1	1	1	1	.7	.7	.7	.7	.7	1	1
1	1	1	1	1	.7	.7	.7	.7	.7	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>

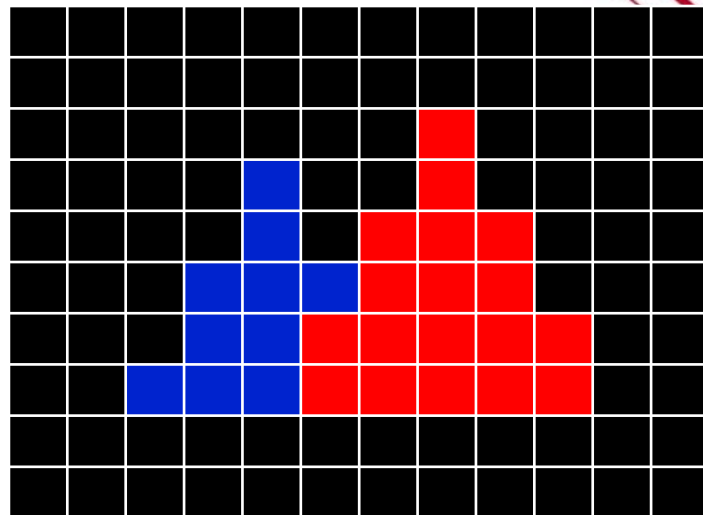
```

Z no NDC
0.99779776

Normalizando
0.99889888

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 (0.998X)

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	.7	1	1	1	1
1	1	1	1	.8	1	1	.7	1	1	1	1
1	1	1	1	.8	1	.7	.7	.7	1	1	1
1	1	1	.8	.8	.8	.7	.7	.7	1	1	1
1	1	1	.8	.8	.7	.7	.7	.7	.7	1	1
1	1	.8	.8	.8	.7	.7	.7	.7	.7	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

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)

$\text{cor_anterior} = \text{framebuffer}[x,y] * \text{transparência}$

$\text{cor_nova} = \text{rbg} * (1 - \text{transparência})$

$\text{framebuffer}[x,y] = \text{cor_anterior} + \text{cor_nova}$

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)

$\text{cor_anterior} = \text{framebuffer}[x,y] * \text{transparência}$

$\text{cor_nova} = \text{rbg} * (1 - \text{transparência})$

$\text{framebuffer}[x,y] = \text{cor_anterior} + \text{cor_nova}$

Computação Gráfica

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