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Computação Gráfica

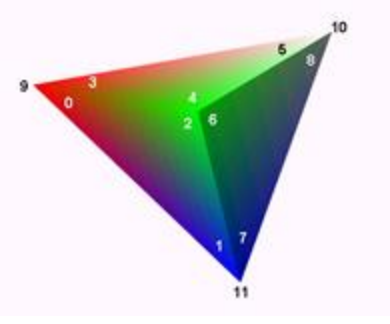
Aula 08x: Revisão 2 Malhas e Grafo de Cena

Tipos de Malhas Triangulares estudadas

- triangleSet
- triangleStripSet
- indexedTriangleStripSet
- indexedFaceSet

TriangleSet

O nó **TriangleSet** representa uma geometria 3D que representa uma coleção de triângulos individuais. Cada triângulo é formado por um conjunto consecutivo de três vértices do nó **Coordinate**. Se o nó de coordenadas não contém um múltiplo de três valores de coordenadas, os vértices restantes devem ser ignorados.



TriangleSet : X3DComposedGeometryNode {

MFNode	[in,out]	attrib	[]	[X3DVertexAttributeNode]
SFNode	[in,out]	color	NULL	[X3DColorNode]
SFNode	**[in,out]**	**coord**	**NULL**	**[X3DCoordinateNode]**
SFNode	[in,out]	fogCoord	NULL	[FogCoordinate]
SFNode	[in,out]	metadata	NULL	[X3DMetadataObject]
SFNode	[in,out]	normal	NULL	[X3DNormalNode]
SFNode	[in,out]	texCoord	NULL	[X3DTextureCoordinateNode]
SFBool	[]	ccw	TRUE	
SFBool	[]	colorPerVertex	TRUE	
SFBool	[]	normalPerVertex	TRUE	
SFBool	[]	solid	TRUE	

}

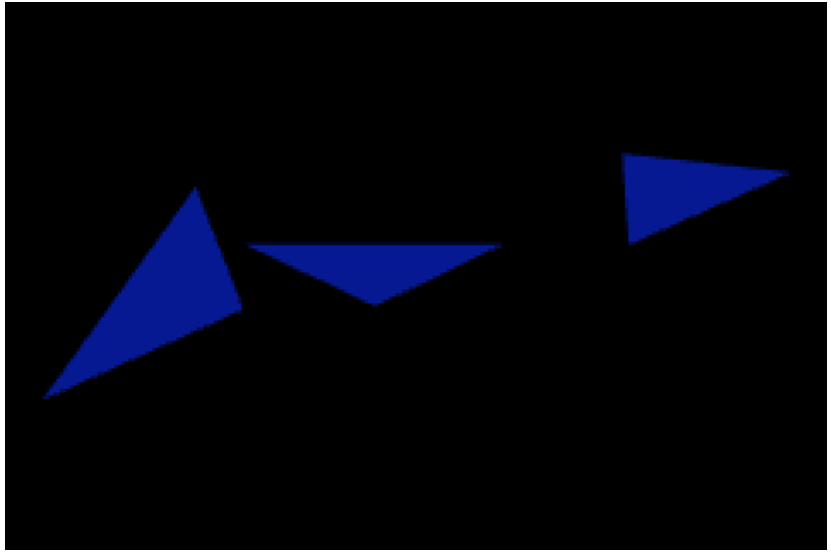
https://www.web3d.org/documents/specifications/19775-1/V3.3/Part01/components/rendering.html#TriangleSet

Exemplo de TriangleSet

```
<X3D>
 <Scene>
  <NavigationInfo headlight="false"/>
  <Viewpoint orientation='0 -1 0 0.05' position='0.13 2.51 11.24'/>
  <Transform>
   <Shape>
    <Appearance>
     <Material emissiveColor='0 .1 0.6'/>
    </Appearance>
    <TriangleSet>
     <Coordinate point='
                -4  1  3
                -2  2  1
                -3  4  0

                 0  2  0
                 2  3  1
                -2  3  1

                 5  5 -2
                 4  3  1
                 6  4  2
              '/>
    </TriangleSet>
   </Shape>
  </Transform>
 </Scene>
</X3D>
```



https://x3dgraphics.com/examples/X3dForWebAuthors/Chapter13GeometryTrianglesQuadrilaterals/TriangleSetExampleIndex.html

TriangleStripSet

Um **TriangleStripSet** representa uma forma geométrica 3D composta por faixas de triângulos. O campo **stripCount** descreve quantos vértices devem ser usados em cada faixa do **Coordinate**. As coordenadas são atribuídas a cada faixa pegando os vértices **stripCount[i]** do campo de coordenadas, onde i é um índice sequencial de stripCount.

TriangleStripSet : X3DComposedGeometryNode {

MFNode	[in,out]	attrib	[]	[X3DVertexAttributeNode]
SFNode	[in,out]	color	NULL	[X3DColorNode]
SFNode	**[in,out]**	**coord**	**NULL**	**[X3DCoordinateNode]**
SFNode	[in,out]	fogCoord	NULL	[FogCoordinate]
SFNode	[in,out]	metadata	NULL	[X3DMetadataObject]
SFNode	[in,out]	normal	NULL	[X3DNormalNode]
MFInt32	**[in,out]**	**stripCount**	**[]**	**[3,∞)**
SFNode	[in,out]	texCoord	NULL	[X3DTextureCoordinateNode]
SFBool	[]	ccw	TRUE	
SFBool	[]	colorPerVertex	TRUE	
SFBool	[]	normalPerVertex	TRUE	
SFBool	[]	solid	TRUE	

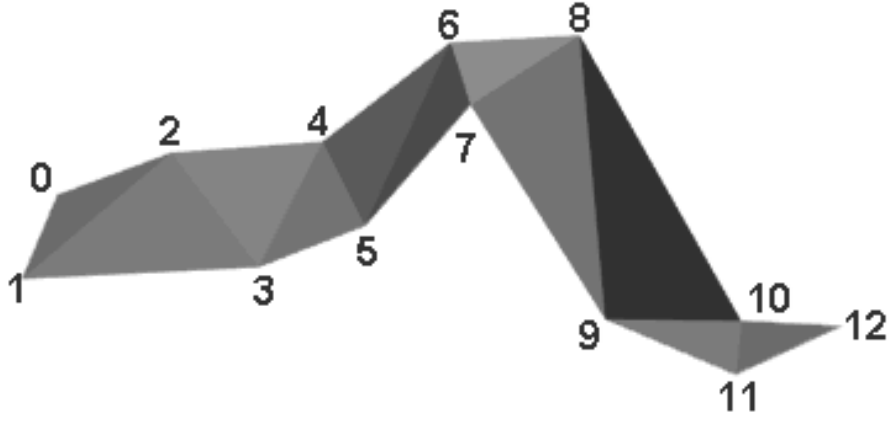
}

https://www.web3d.org/documents/specifications/19775-1/V3.3/Part01/components/rendering.html#TriangleStripSet

TriangleStripSet (exemplo)

```
<Shape>
    <TriangleStripSet stripCount='13'>
        <Coordinate point='
              -4.0 -1.0 -0.5   -> P0
              -4.5 -2.0 -0.5   -> P1
              -3.0 -0.5  0.0   -> P2
              -2.5 -1.5 -0.5   -> P3
              -2.0 -0.5 -1.0   -> P4
              -1.5 -1.5 -0.5   -> P5
              -0.5  0.5 -0.5   -> P6
               0.0  0.0  0.0   -> P7
               1.0  0.5 -0.5   -> P8
               1.5 -2.0 -1.0   -> P9
               2.5 -2.0 -0.5   -> P10
               2.5 -2.5 -0.5   -> P11
               3.5 -2.0 -1.0   -> P12
        '/>
    </TriangleStripSet>
    <Appearance> <Material diffuseColor='0.5 0.5 0.5'/> </Appearance>
</Shape>
```

Os vértices são conectados de 3 em 3. Assim o primeiro triângulos será ligando os vértices (0, 1, 2), o segundo (1, 2, 3) e assim por diante, até chegar a contagem definida em stripCount. Perceba que stripCount é uma lista.



https://www.web3d.org/documents/specifications/19775-1/V3.3/Part01/components/rendering.html#TriangleStripSet

IndexedTriangleStripSet

Um **IndexedTriangleStripSet** representa uma forma 3D composta de um conjunto de triângulos em forma de uma tira, são usados nos índices do campo **index** para especificar como montar faixa de triângulos. Um índice de "−1" indica que a faixa atual terminou e a próxima começa.

IndexedTriangleStripSet : X3DComposedGeometryNode {

MFInt32	[in]	set_index	[]	[0,∞) or −1
MFNode	[in,out]	attrib	[]	[X3DVertexAttributeNode]
SFNode	[in,out]	color	NULL	[X3DColorNode]
SFNode	**[in,out]**	**coord**	**NULL**	**[X3DCoordinateNode]**
SFNode	[in,out]	fogCoord	NULL	[FogCoordinate]
SFNode	[in,out]	metadata	NULL	[X3DMetadataObject]
SFNode	[in,out]	normal	NULL	[X3DNormalNode]
SFNode	[in,out]	texCoord	NULL	[X3DTextureCoordinateNode]
SFBool	[]	ccw	TRUE	
SFBool	[]	colorPerVertex	TRUE	
SFBool	[]	normalPerVertex	TRUE	
SFBool	[]	solid	TRUE	
MFInt32	**[]**	**index**	**[]**	**[0,∞) or −1**

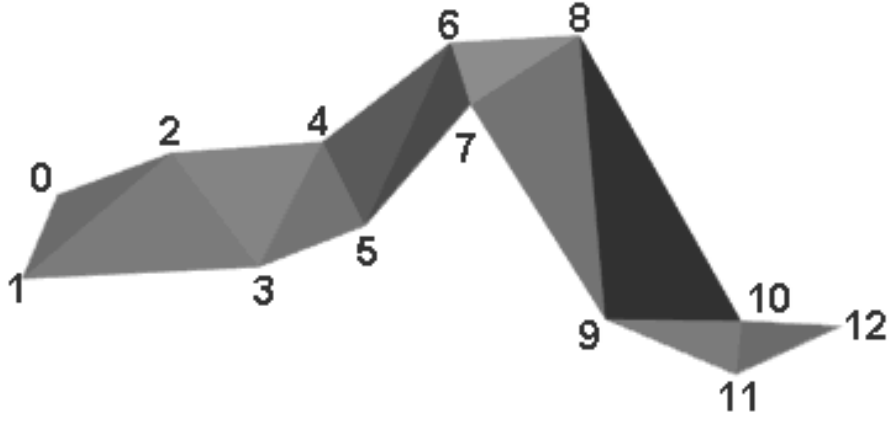
}

https://www.web3d.org/documents/specifications/19775-1/V3.3/Part01/components/rendering.html#IndexedTriangleStripSet

IndexedTriangleStripSet (exemplo)

```
<Shape>
    <IndexedTriangleStripSet index='0 1 2 3 4 5 6 7 8 9 10 11 12 -1'>
        <Coordinate point='
              -4.0 -1.0 -0.5   -> P0
              -4.5 -2.0 -0.5   -> P1
              -3.0 -0.5  0.0   -> P2
              -2.5 -1.5 -0.5   -> P3
              -2.0 -0.5 -1.0   -> P4
              -1.5 -1.5 -0.5   -> P5
              -0.5  0.5 -0.5   -> P6
               0.0  0.0  0.0   -> P7
               1.0  0.5 -0.5   -> P8
               1.5 -2.0 -1.0   -> P9
               2.5 -2.0 -0.5   -> P10
               2.5 -2.5 -0.5   -> P11
               3.5 -2.0 -1.0   -> P12
        '/>
    </IndexedTriangleStripSet>
    <Appearance> <Material diffuseColor='0.5 0.5 0.5'/> </Appearance>
</Shape>
```

Os vértices são conectados seguindo a ordem definida no campo index. Ligando de 3 em 3 vértices até encontrar um valor -1. Outras listas de índices podem aparecer na sequencia.



https://www.web3d.org/documents/specifications/19775-1/V3.3/Part01/components/rendering.html#IndexedTriangleStripSet

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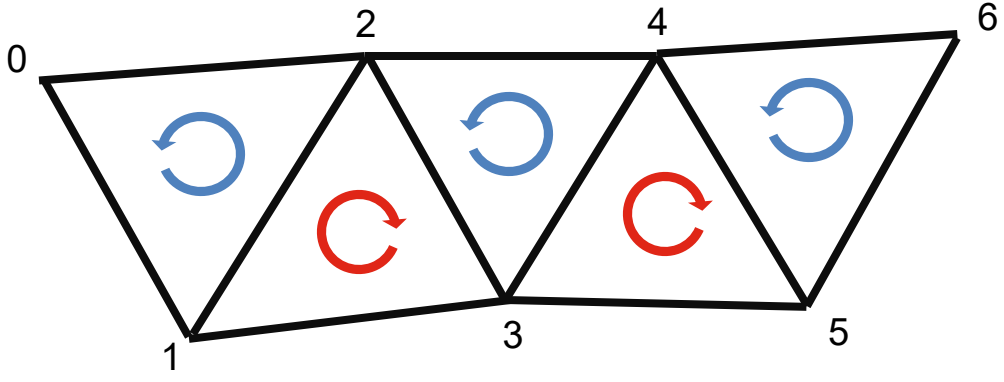
Cuidado

A direção de montagem dos triângulos precisa ser constantemente alternada, senão a detecção de triângulos irá falhar



Um dos truques é inverter a ordem de conexão, assim nos triângulos pares, inverte a conexão de dois vértices.

Por exemplo, conecte: (0,1,2), depois (1,3,2), depois (2,3,4) e assim por diante.

IndexedFaceSet

Um **IndexedFaceSet** representa uma forma 3D composta de um conjunto de polígonos, são usados nos índices do campo **coordIndex** para especificar como montar os triângulos, o campo **colordIndex** para especificar como mapear as cores por vértices, e o campo **texCoordIndex** para mapear as coordenadas de textura.

```
IndexedFaceSet : X3DComposedGeometryNode {
  MFInt32 [in]     set_colorIndex
  MFInt32 [in]     set_coordIndex
  MFInt32 [in]     set_normalIndex
  MFInt32 [in]     set_texCoordIndex
  MFNode  [in,out] attrib          []   [X3DVertexAttributeNode]
  SFNode  [in,out] color           NULL [X3DColorNode]
  SFNode  [in,out] coord           NULL [X3DCoordinateNode]
  SFNode  [in,out] fogCoord        NULL [FogCoordinate]
  SFNode  [in,out] metadata        NULL [X3DMetadataObject]
  SFNode  [in,out] normal          NULL [X3DNormalNode]
  SFNode  [in,out] texCoord        NULL [X3DTextureCoordinateNode]
  SFBool  []       ccw             TRUE
  MFInt32 []       colorIndex      []   [0,∞) or -1
  SFBool  []       colorPerVertex  TRUE
  SFBool  []       convex          TRUE
  MFInt32 []       coordIndex      []   [0,∞) or -1
  SFFloat []       creaseAngle     0    [0,∞)
  MFInt32 []       normalIndex     []   [0,∞) or -1
  SFBool  []       normalPerVertex TRUE
  SFBool  []       solid           TRUE
  MFInt32 []       texCoordIndex   []   [-1,∞)
}
```

https://www.web3d.org/documents/specifications/19775-1/V3.3/Part01/components/geometry3D.html#IndexedFaceSet

IndexedFaceSet

O nó IndexedFaceSet representa uma forma 3D formada pela construção de faces (polígonos) de vértices listados no campo coord.

IndexedFaceSet usa os índices em seu campo coordIndex para especificar as faces poligonais indexando nas coordenadas no nó Coordinate. Um índice de "−1" indica que a face atual terminou e a próxima começa.

Cada face do IndexedFaceSet deve ter:

- pelo menos três vértices não coincidentes;

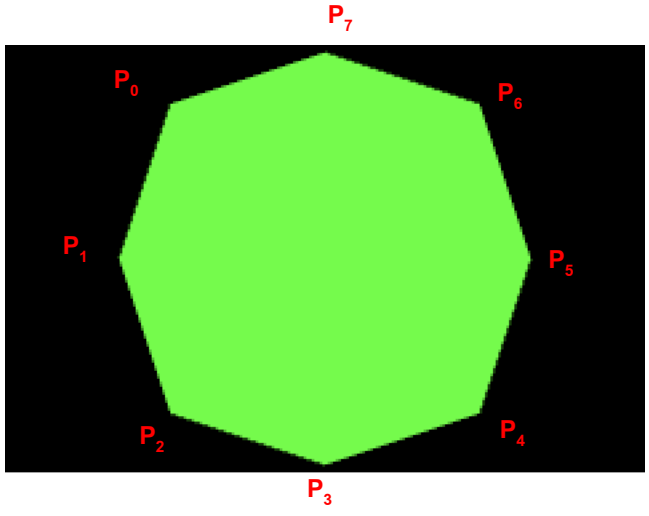
- vértices que definem um polígono planar;

- vértices não possuem auto-intersecção.

 https://www.web3d.org/documents/specifications/19775-1/V3.3/Part01/components/geometry3D.html#IndexedFaceSet

Exemplo IndexedFaceSet

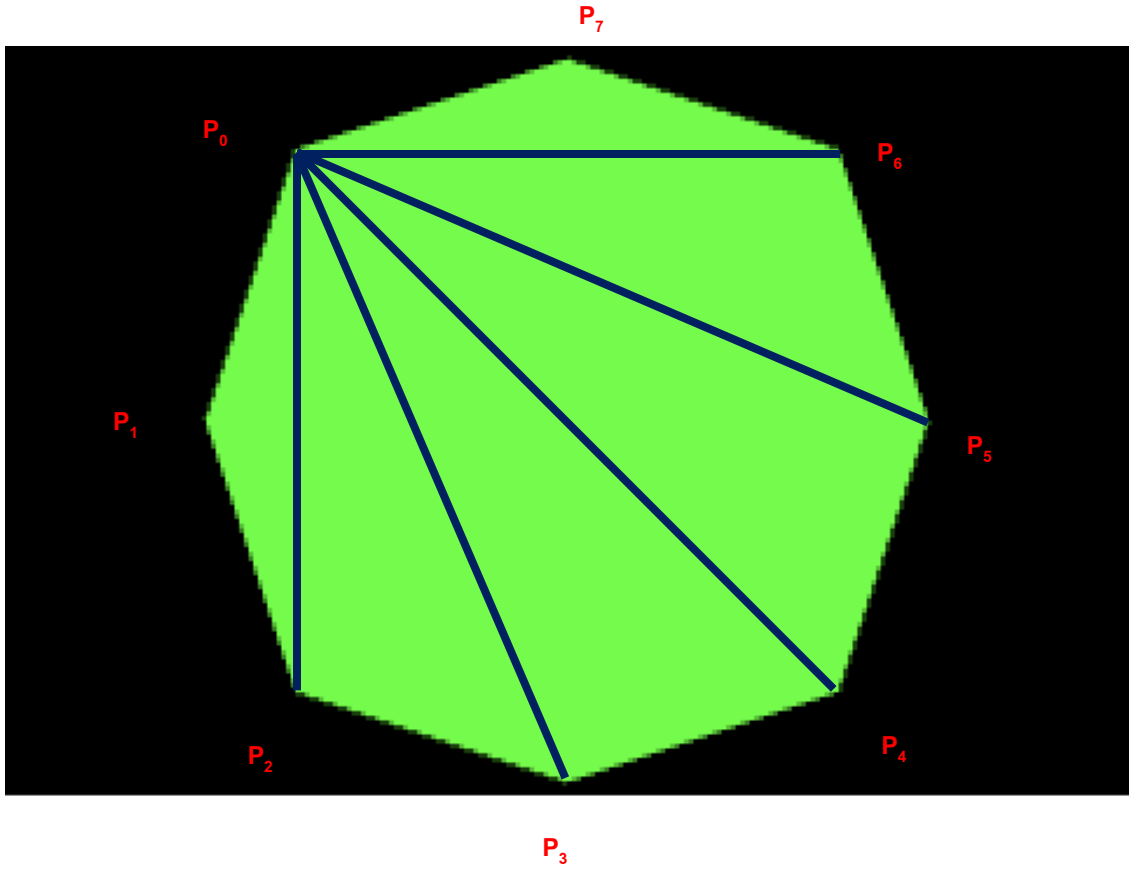
```
<Shape>
    <IndexedFaceSet coordIndex='0 1 2 3 4 5 6 7 -1'>
        <Coordinate point='
                -3  3 0   -> P0
                -4  0 0   -> P1
                -3 -3 0   -> P2
                 0 -4 0   -> P3
                 3 -3 0   -> P4
                 4  0 0   -> P5
                 3  3 0   -> P6
                 0  4 0   -> P7
         '/>
    </IndexedFaceSet>
    <Appearance> <Material emissiveColor='0 1 0'/> </Appearance>
</Shape>
```



Os pontos são o contorna da superfície.

Exemplo IndexedFaceSet

Possível solução



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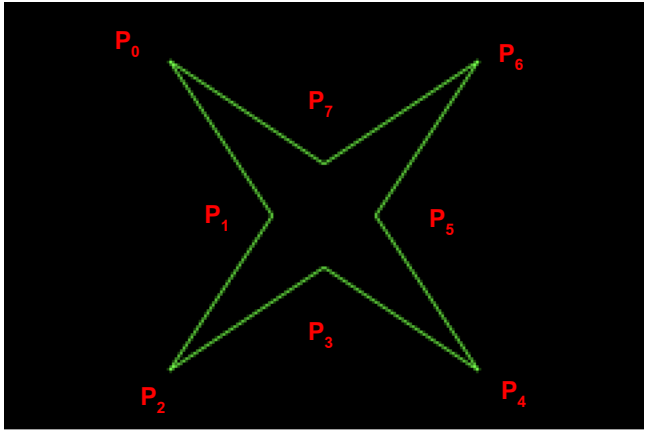
Exemplo IndexedFaceSet

Mas e se a geometria fosse assim:

```
<Shape>
    <IndexedFaceSet coordIndex='0 1 2 3 4 5 6 7 -1'>
        <Coordinate point='
                -3  3 0   -> P0
                -1  0 0   -> P1
                -3 -3 0   -> P2
                 0 -1 0   -> P3
                 3 -3 0   -> P4
                 1  0 0   -> P5
                 3  3 0   -> P6
                 0  1 0   -> P7
         '/>
    </IndexedFaceSet>
    <Appearance> <Material emissiveColor='0 1 0'/> </Appearance>
</Shape>
```



Dessa forma também não funcionaria pela especificação X3D e geraria uma geometria errada. Para funcionar você deveria especifica **convex="false",** porém não vamos trabalhar com essa situação.

Grafo de Cena

Criando Matriz Identidade

Início

```
<Scene>
 <Transform scale="2 2 2">
  <Shape>
   <TriangleSet>
    <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
   </TriangleSet>
   <Appearance>
    <Material diffuseColor='1 0 0'/>
   </Appearance>
  </Shape>
  <Transform scale="2 1 1">
   <Transform translation="0 -1 -1">
    <Shape>
     <TriangleSet>
      <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
     </TriangleSet>
     <Appearance>
      <Material diffuseColor='0 1 0'/>
     </Appearance>
    </Shape>
   </Transform>
   <Transform translation="0 1 -2">
    <Transform rotation="0 0 1 3.14">
     <Shape>
      <TriangleSet>
       <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
      </TriangleSet>
      <Appearance>
       <Material diffuseColor='0 0 1'/>
      </Appearance>
     </Shape>
    </Transform>
   </Transform>
  </Transform>
 </Transform>
</Scene>
```

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

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Empilhando e Atualizando Transformação

```
<Scene>
 <Transform scale="2 2 2">
  <Shape>
   <TriangleSet>
    <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
   </TriangleSet>
   <Appearance>
    <Material diffuseColor='1 0 0'/>
   </Appearance>
  </Shape>
  <Transform scale="2 1 1">
   <Transform translation="0 -1 -1">
    <Shape>
     <TriangleSet>
      <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
     </TriangleSet>
     <Appearance>
      <Material diffuseColor='0 1 0'/>
     </Appearance>
    </Shape>
   </Transform>
   <Transform translation="0 1 -2">
    <Transform rotation="0 0 1 3.14">
     <Shape>
      <TriangleSet>
       <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
      </TriangleSet>
      <Appearance>
       <Material diffuseColor='0 0 1'/>
      </Appearance>
     </Shape>
    </Transform>
   </Transform>
  </Transform>
 </Transform>
</Scene>
```

push

$$\begin{bmatrix}1&0&0&0\\0&1&0&0\\0&0&1&0\\0&0&0&1\end{bmatrix} \times \begin{bmatrix}2&0&0&0\\0&2&0&0\\0&0&2&0\\0&0&0&1\end{bmatrix}$$

$$\begin{bmatrix}\mathbf{2}&\mathbf{0}&\mathbf{0}&\mathbf{0}\\\mathbf{0}&\mathbf{2}&\mathbf{0}&\mathbf{0}\\\mathbf{0}&\mathbf{0}&\mathbf{2}&\mathbf{0}\\\mathbf{0}&\mathbf{0}&\mathbf{0}&\mathbf{1}\end{bmatrix}$$

$$\begin{bmatrix}1&0&0&0\\0&1&0&0\\0&0&1&0\\0&0&0&1\end{bmatrix}$$

MATRIZ

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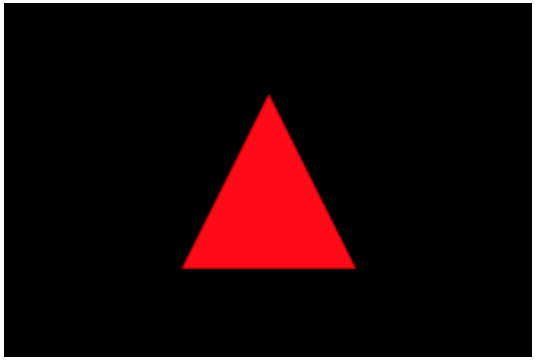
Desenhando Triângulo Vermelho

```
<Scene>
 <Transform scale="2 2 2">
  <Shape>
   <TriangleSet>
    <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
   </TriangleSet>
   <Appearance>
    <Material diffuseColor='1 0 0'/>
   </Appearance>
  </Shape>
  <Transform scale="2 1 1">
   <Transform translation="0 -1 -1">
    <Shape>
     <TriangleSet>
      <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
     </TriangleSet>
     <Appearance>
      <Material diffuseColor='0 1 0'/>
     </Appearance>
    </Shape>
   </Transform>
   <Transform translation="0 1 -2">
    <Transform rotation="0 0 1 3.14">
     <Shape>
      <TriangleSet>
       <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
      </TriangleSet>
      <Appearance>
       <Material diffuseColor='0 0 1'/>
      </Appearance>
     </Shape>
    </Transform>
   </Transform>
  </Transform>
 </Transform>
</Scene>
```

draw



$$\begin{bmatrix} 2 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

MATRIZ

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

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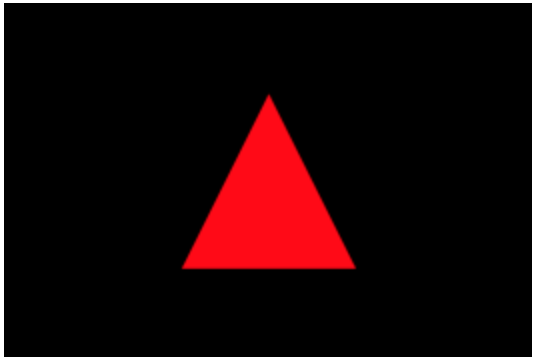
Empilhando e Atualizando Transformação

```
<Scene>
 <Transform scale="2 2 2">
  <Shape>
   <TriangleSet>
    <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
   </TriangleSet>
   <Appearance>
    <Material diffuseColor='1 0 0'/>
   </Appearance>
  </Shape>
  <Transform scale="2 1 1">
   <Transform translation="0 -1 -1">
    <Shape>
     <TriangleSet>
      <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
     </TriangleSet>
     <Appearance>
      <Material diffuseColor='0 1 0'/>
     </Appearance>
    </Shape>
   </Transform>
   <Transform translation="0 1 -2">
    <Transform rotation="0 0 1 3.14">
     <Shape>
      <TriangleSet>
       <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
      </TriangleSet>
      <Appearance>
       <Material diffuseColor='0 0 1'/>
      </Appearance>
     </Shape>
    </Transform>
   </Transform>
  </Transform>
 </Transform>
</Scene>
```

push



$$\begin{bmatrix} 2 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} 2 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} \mathbf{4} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{2} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{2} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{1} \end{bmatrix}$$

$$\begin{bmatrix} 2 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

MATRIZ

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

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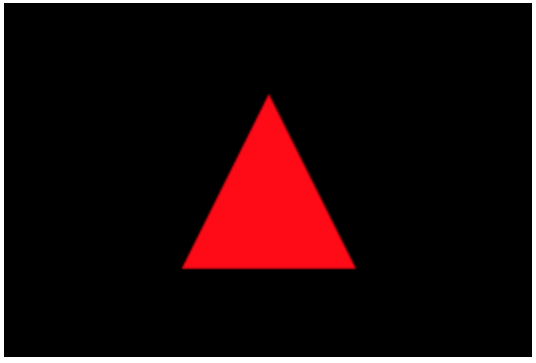
Empilhando e Atualizando Transformação

```
<Scene>
 <Transform scale="2 2 2">
  <Shape>
   <TriangleSet>
    <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
   </TriangleSet>
   <Appearance>
    <Material diffuseColor='1 0 0'/>
   </Appearance>
  </Shape>
  <Transform scale="2 1 1">
   <Transform translation="0 -1 -1">
    <Shape>
     <TriangleSet>
      <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
     </TriangleSet>
     <Appearance>
      <Material diffuseColor='0 1 0'/>
     </Appearance>
    </Shape>
   </Transform>
   <Transform translation="0 1 -2">
    <Transform rotation="0 0 1 3.14">
     <Shape>
      <TriangleSet>
       <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
      </TriangleSet>
      <Appearance>
       <Material diffuseColor='0 0 1'/>
      </Appearance>
     </Shape>
    </Transform>
   </Transform>
  </Transform>
 </Transform>
</Scene>
```

push



$$\begin{bmatrix} 4 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & -1 \\ 0 & 0 & 1 & -1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} \mathbf{4} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{2} & \mathbf{0} & \mathbf{-2} \\ \mathbf{0} & \mathbf{0} & \mathbf{2} & \mathbf{-2} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{1} \end{bmatrix}$$

$$\begin{bmatrix} 4 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

MATRIZ

$$\begin{bmatrix} 2 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

PILHA

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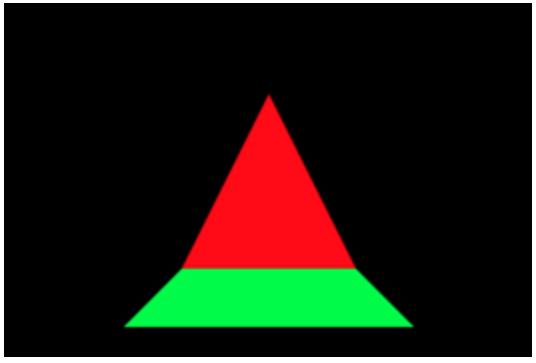
Desenhando Triângulo Verde

```
<Scene>
 <Transform scale="2 2 2">
  <Shape>
   <TriangleSet>
    <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
   </TriangleSet>
   <Appearance>
    <Material diffuseColor='1 0 0'/>
   </Appearance>
  </Shape>
  <Transform scale="2 1 1">
   <Transform translation="0 -1 -1">
    <Shape>
     <TriangleSet>
      <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
     </TriangleSet>
     <Appearance>
      <Material diffuseColor='0 1 0'/>
     </Appearance>
    </Shape>
   </Transform>
   <Transform translation="0 1 -2">
    <Transform rotation="0 0 1 3.14">
     <Shape>
      <TriangleSet>
       <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
      </TriangleSet>
      <Appearance>
       <Material diffuseColor='0 0 1'/>
      </Appearance>
     </Shape>
    </Transform>
   </Transform>
  </Transform>
 </Transform>
</Scene>
```

draw



$$\begin{bmatrix} 4 & 0 & 0 & 0 \\ 0 & 2 & 0 & -2 \\ 0 & 0 & 2 & -2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

MATRIZ

$$\begin{bmatrix} 4 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

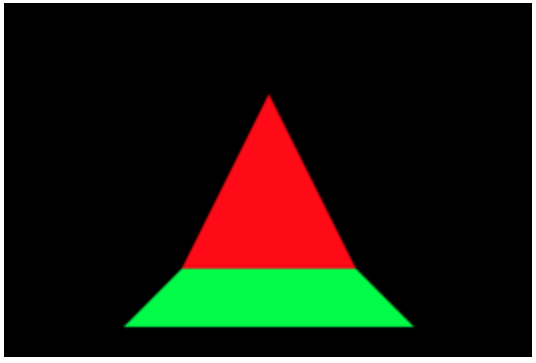
$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

PILHA

Desempilhando e Atualizando Transformação

```
<Scene>
 <Transform scale="2 2 2">
  <Shape>
   <TriangleSet>
    <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
   </TriangleSet>
   <Appearance>
    <Material diffuseColor='1 0 0'/>
   </Appearance>
  </Shape>
  <Transform scale="2 1 1">
   <Transform translation="0 -1 -1">
    <Shape>
     <TriangleSet>
      <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
     </TriangleSet>
     <Appearance>
      <Material diffuseColor='0 1 0'/>
     </Appearance>
    </Shape>
   </Transform>
   <Transform translation="0 1 -2">
    <Transform rotation="0 0 1 3.14">
     <Shape>
      <TriangleSet>
       <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
      </TriangleSet>
      <Appearance>
       <Material diffuseColor='0 0 1'/>
      </Appearance>
     </Shape>
    </Transform>
   </Transform>
  </Transform>
 </Transform>
</Scene>
```

pop



$$\begin{bmatrix} 4 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

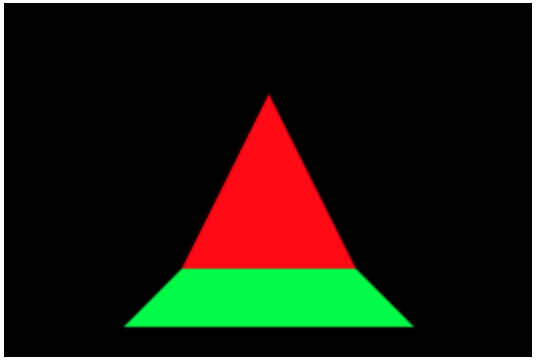
PILHA

$$\begin{bmatrix} 4 & 0 & 0 & 0 \\ 0 & 2 & 0 & -2 \\ 0 & 0 & 2 & -2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

MATRIZ

Empilhando e Atualizando Transformação

```
<Scene>
 <Transform scale="2 2 2">
  <Shape>
   <TriangleSet>
    <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
   </TriangleSet>
   <Appearance>
    <Material diffuseColor='1 0 0'/>
   </Appearance>
  </Shape>
  <Transform scale="2 1 1">
   <Transform translation="0 -1 -1">
    <Shape>
     <TriangleSet>
      <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
     </TriangleSet>
     <Appearance>
      <Material diffuseColor='0 1 0'/>
     </Appearance>
    </Shape>
   </Transform>
   <Transform translation="0 1 -2">
    <Transform rotation="0 0 1 3.14">
     <Shape>
      <TriangleSet>
       <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
      </TriangleSet>
      <Appearance>
       <Material diffuseColor='0 0 1'/>
      </Appearance>
     </Shape>
    </Transform>
   </Transform>
  </Transform>
 </Transform>
</Scene>
```



$$\begin{bmatrix} 4 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & -2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

push

$$\begin{bmatrix} \mathbf{4} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{2} & \mathbf{0} & \mathbf{2} \\ \mathbf{0} & \mathbf{0} & \mathbf{2} & \mathbf{-4} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{1} \end{bmatrix}$$

$$\begin{bmatrix} 4 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

MATRIZ

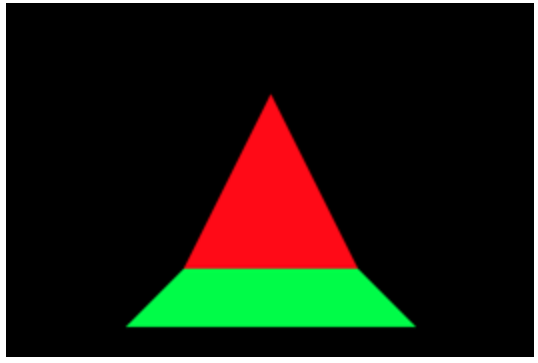
$$\begin{bmatrix} 2 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

PILHA

Empilhando e Atualizando Transformação

```
<Scene>
 <Transform scale="2 2 2">
  <Shape>
   <TriangleSet>
    <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
   </TriangleSet>
   <Appearance>
    <Material diffuseColor='1 0 0'/>
   </Appearance>
  </Shape>
  <Transform scale="2 1 1">
   <Transform translation="0 -1 -1">
    <Shape>
     <TriangleSet>
      <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
     </TriangleSet>
     <Appearance>
      <Material diffuseColor='0 1 0'/>
     </Appearance>
    </Shape>
   </Transform>
   <Transform translation="0 1 -2">
    <Transform rotation="0 0 1 3.14">
     <Shape>
      <TriangleSet>
       <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
      </TriangleSet>
      <Appearance>
       <Material diffuseColor='0 0 1'/>
      </Appearance>
     </Shape>
    </Transform>
   </Transform>
  </Transform>
 </Transform>
</Scene>
```



push

$$\begin{bmatrix} 4 & 0 & 0 & 0 \\ 0 & 2 & 0 & 2 \\ 0 & 0 & 2 & -4 \\ 0 & 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} \mathbf{-4} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{-2} & \mathbf{0} & \mathbf{2} \\ \mathbf{0} & \mathbf{0} & \mathbf{2} & \mathbf{-4} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{1} \end{bmatrix}$$

$$\begin{bmatrix} 4 & 0 & 0 & 0 \\ 0 & 2 & 0 & 2 \\ 0 & 0 & 2 & -4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

MATRIZ

$$\begin{bmatrix} 4 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

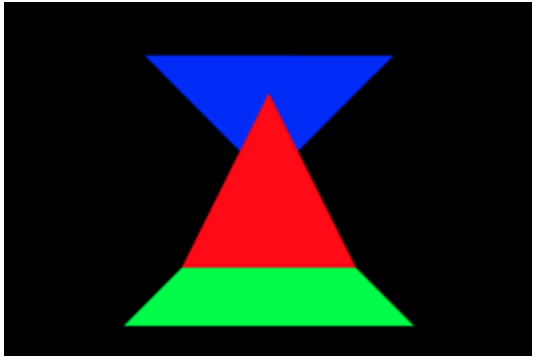
PILHA

Insper

Desenhando Triângulo Azul

```
<Scene>
 <Transform scale="2 2 2">
  <Shape>
   <TriangleSet>
    <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
   </TriangleSet>
   <Appearance>
    <Material diffuseColor='1 0 0'/>
   </Appearance>
  </Shape>
  <Transform scale="2 1 1">
   <Transform translation="0 -1 -1">
    <Shape>
     <TriangleSet>
      <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
     </TriangleSet>
     <Appearance>
      <Material diffuseColor='0 1 0'/>
     </Appearance>
    </Shape>
   </Transform>
   <Transform translation="0 1 -2">
    <Transform rotation="0 0 1 3.14">
     <Shape>
      <TriangleSet>
       <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
      </TriangleSet>
      <Appearance>
       <Material diffuseColor='0 0 1'/>
      </Appearance>
     </Shape>
    </Transform>
   </Transform>
  </Transform>
 </Transform>
</Scene>
```

draw



$$\begin{bmatrix} -4 & 0 & 0 & 0 \\ 0 & -2 & 0 & 2 \\ 0 & 0 & 2 & -4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

MATRIZ

$$\begin{bmatrix} 4 & 0 & 0 & 0 \\ 0 & 2 & 0 & 2 \\ 0 & 0 & 2 & -4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 4 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

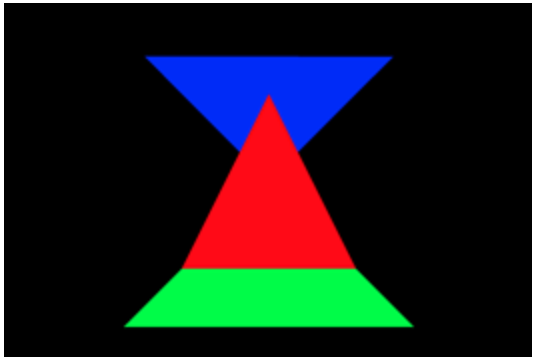
$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

PILHA

Desempilhando e Atualizando Transformação

```
<Scene>
 <Transform scale="2 2 2">
  <Shape>
   <TriangleSet>
    <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
   </TriangleSet>
   <Appearance>
    <Material diffuseColor='1 0 0'/>
   </Appearance>
  </Shape>
  <Transform scale="2 1 1">
   <Transform translation="0 -1 -1">
    <Shape>
     <TriangleSet>
      <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
     </TriangleSet>
     <Appearance>
      <Material diffuseColor='0 1 0'/>
     </Appearance>
    </Shape>
   </Transform>
   <Transform translation="0 1 -2">
    <Transform rotation="0 0 1 3.14">
     <Shape>
      <TriangleSet>
       <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
      </TriangleSet>
      <Appearance>
       <Material diffuseColor='0 0 1'/>
      </Appearance>
     </Shape>
    </Transform>
   </Transform>
  </Transform>
 </Transform>
</Scene>
```

pop



$$\begin{bmatrix} 4 & 0 & 0 & 0 \\ 0 & 2 & 0 & 2 \\ 0 & 0 & 2 & -4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 4 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} -4 & 0 & 0 & 0 \\ 0 & -2 & 0 & 2 \\ 0 & 0 & 2 & -4 \\ 0 & 0 & 0 & 1 \end{bmatrix} \leftarrow \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

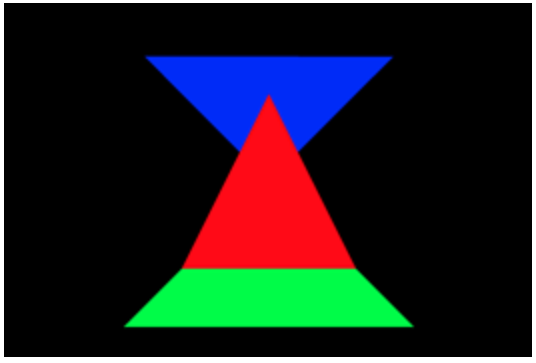
MATRIZ PILHA

Insper

Desempilhando e Atualizando Transformação

```
<Scene>
 <Transform scale="2 2 2">
  <Shape>
   <TriangleSet>
    <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
   </TriangleSet>
   <Appearance>
    <Material diffuseColor='1 0 0'/>
   </Appearance>
  </Shape>
  <Transform scale="2 1 1">
   <Transform translation="0 -1 -1">
    <Shape>
     <TriangleSet>
      <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
     </TriangleSet>
     <Appearance>
      <Material diffuseColor='0 1 0'/>
     </Appearance>
    </Shape>
   </Transform>
   <Transform translation="0 1 -2">
    <Transform rotation="0 0 1 3.14">
     <Shape>
      <TriangleSet>
       <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
      </TriangleSet>
      <Appearance>
       <Material diffuseColor='0 0 1'/>
      </Appearance>
     </Shape>
    </Transform>
   </Transform>
  </Transform>
 </Transform>
</Scene>
```

pop



$$\begin{bmatrix} 4 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 2 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 4 & 0 & 0 & 0 \\ 0 & 2 & 0 & 2 \\ 0 & 0 & 2 & -4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

MATRIZ

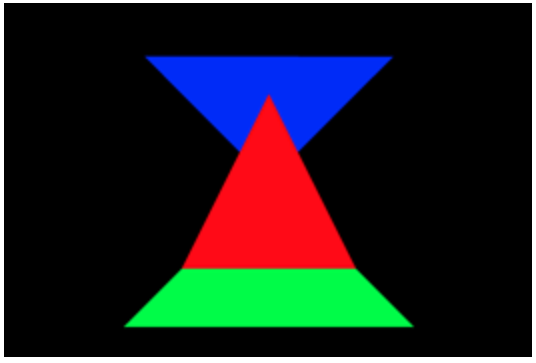
PILHA

Insper

Desempilhando e Atualizando Transformação

```
<Scene>
 <Transform scale="2 2 2">
  <Shape>
   <TriangleSet>
    <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
   </TriangleSet>
   <Appearance>
    <Material diffuseColor='1 0 0'/>
   </Appearance>
  </Shape>
  <Transform scale="2 1 1">
   <Transform translation="0 -1 -1">
    <Shape>
     <TriangleSet>
      <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
     </TriangleSet>
     <Appearance>
      <Material diffuseColor='0 1 0'/>
     </Appearance>
    </Shape>
   </Transform>
   <Transform translation="0 1 -2">
    <Transform rotation="0 0 1 3.14">
     <Shape>
      <TriangleSet>
       <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
      </TriangleSet>
      <Appearance>
       <Material diffuseColor='0 0 1'/>
      </Appearance>
     </Shape>
    </Transform>
   </Transform>
  </Transform>
 </Transform>
</Scene>
```

pop



$$\begin{bmatrix} 2 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 4 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

MATRIZ

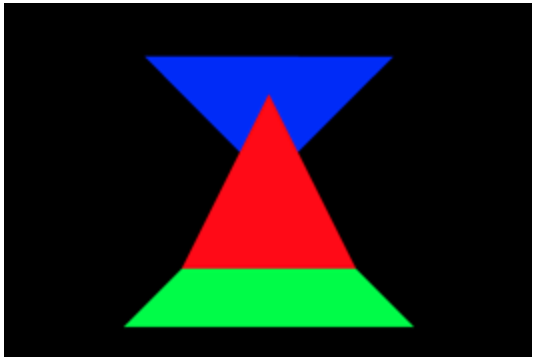
PILHA

Insper

Desempilhando e Atualizando Transformação

```
<Scene>
 <Transform scale="2 2 2">
  <Shape>
   <TriangleSet>
    <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
   </TriangleSet>
   <Appearance>
    <Material diffuseColor='1 0 0'/>
   </Appearance>
  </Shape>
  <Transform scale="2 1 1">
   <Transform translation="0 -1 -1">
    <Shape>
     <TriangleSet>
      <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
     </TriangleSet>
     <Appearance>
      <Material diffuseColor='0 1 0'/>
     </Appearance>
    </Shape>
   </Transform>
   <Transform translation="0 1 -2">
    <Transform rotation="0 0 1 3.14">
     <Shape>
      <TriangleSet>
       <Coordinate point='-1 -1 0 1 -1 0 0 1 0'/>
      </TriangleSet>
      <Appearance>
       <Material diffuseColor='0 0 1'/>
      </Appearance>
     </Shape>
    </Transform>
   </Transform>
  </Transform>
 </Transform>
</Scene>
```

pop



$$\begin{bmatrix} 2 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

MATRIZ

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

PILHA

Insper

Insper

Computação Gráfica

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