U.PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

TP2 – Geometric Transformations

Concepts and Practice

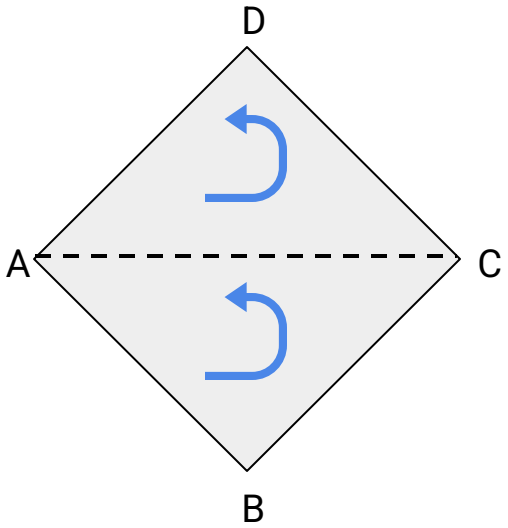
Teresa Matos
20 February 2024

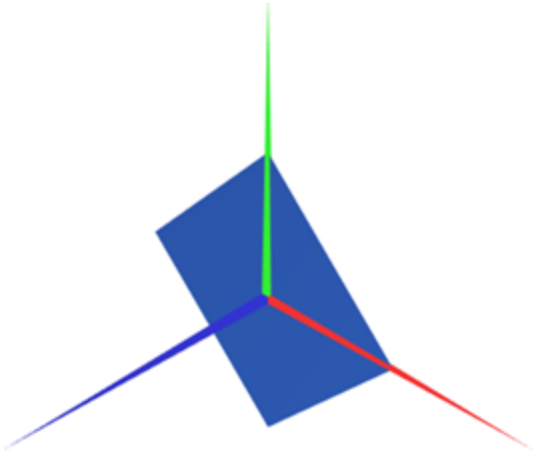
Previous lesson

Last week we learnt how to create geometries using **vertices** and **indices**

```
this.vertices = {
    xA,yA,zA,
    xB,yB,zB,
    xC,yC,zC,
    xD,yD,zD
}

this.indices = {
     0, 1, 2,
     0, 2, 3
}
```





Transformation matrices in OpenGL/WebGL

Geometric transformations are used to **move, scale** and **rotate** the scene objects

The geometric transformations may be represented using **vectors** or **matrices**

For the 3D space, we use **square matrices** with 4x4 dimensions

WebGL matrices are **written differently** from their mathematical equivalent

Math translation matrix

$$\begin{bmatrix} 1 & 0 & 0 & T_x \\ 0 & 1 & 0 & T_y \\ 0 & 0 & 1 & T_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Transposed

(columns↔rows)

OpenGL/WebGL equivalent

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ T_x & T_y & T_z & 1 \end{bmatrix}$$

Transformation matrices in WebCGF

Geometric transformations are applied to the scene – **transformation matrix**

They **affect all elements** drawn after its application

We can define and apply these transformations using **vectors** or **matrices**

In the **WebCGF** library:

Functions for vectors

```
CGFscene.translate(x,y,z)
CGFscene.scale(x,y,z)
CGFscene.rotate(angle,x,y,z)
```

Functions for matrices

```
CGFscene.multMatrix(matrix[4x4])
```

Combining/multiplying transformations

Several transformations may be combined as follows, in the form of matrices:

Example: Apply a rotation in X axis, then a translation (as seen in theory class)

$$\begin{bmatrix} x_f \\ y_f \\ z_f \\ 1 \end{bmatrix} = \boldsymbol{T}(T_x, T_y, T_z).\boldsymbol{R}_x(\alpha).\begin{bmatrix} x_i \\ y_i \\ z_i \\ 1 \end{bmatrix}$$

The matrices are applied **“from right to left”**, in reverse order of how it is described textually

Combining transformations in WebCGF

Using this example, how would we apply the matrices in our WebCGF code?

In `display()` function of **MyScene**:

```
display(){
  …
  matrixRotate = […]
  matrixTranslate = […]

  this.multMatrix(?)
  this.multMatrix(?)
  this.object.display();

}
```

Creating the matrices

Applying matrices

Call for object draw, after transformations

Combining transformations in WebCGF

Transformations are written in **reverse order** of how it is “described textually”

```
display(){
  …
  matrixRotate = […]
  matrixTranslate = […]

  this.multMatrix(matrixTranslate);
  this.multMatrix(matrixRotate);
  this.object.display();

}
```

Or using **vector** functions:

```
display(){
  …

  this.translate(…);
  this.rotate(…);
  this.object.display();

}
```

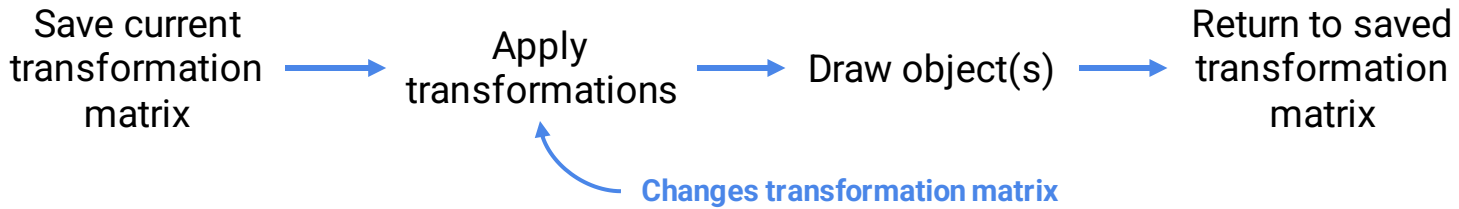
Transformations for multiple objects in WebCGF

Considering that transformations affect all objects drawn after its application:

*How to apply **different transformations** to different objects?*

The scene (**CGFscene**) contains a **matrix stack**, which can be used to store and recover previous versions of the transformation matrix

The **process** of applying the transformations to **specific objects** is as follows:



Transformations for multiple objects in WebCGF

The **CGFscene** class provides functions for manipulating the matrix stack

```
display(){
  this.loadIdentity();
  …
  this.pushMatrix();
  this.multMatrix(…);
  …
  //Draw the objects
  this.popMatrix();
  …
  //Repeat the process
}
```

Sets the scene's transformation matrix to the identity matrix (already in provided code)

Saves current transformation matrix to the stack

Sets the scene's transformation matrix to the previously saved matrix

These functions can be **nested** to create complex objects composed of **different geometries**

Note: `loadIdentity()` is already present in the `display()` function in the provided source code. You don't need to use it again.