U.PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

Computer Graphics
L.EIC

TP4 - Textures

Concepts and Practice

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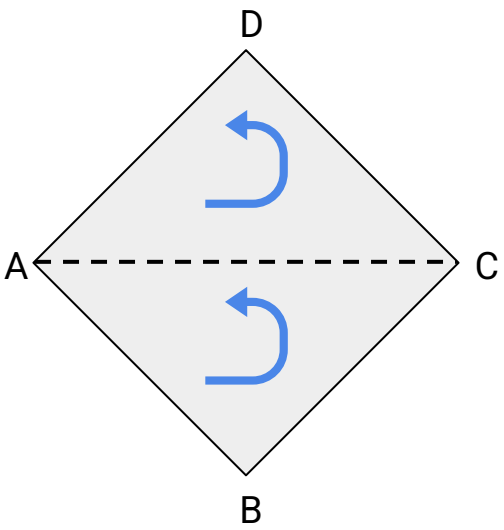
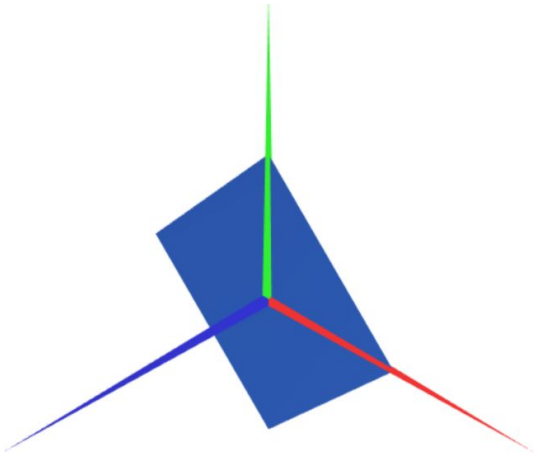
Previous lessons

We have 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
}
```





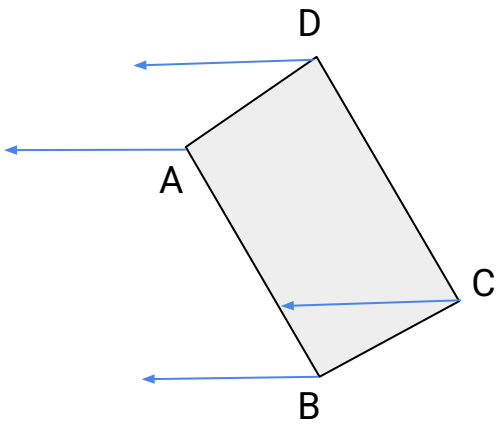
Previous lessons

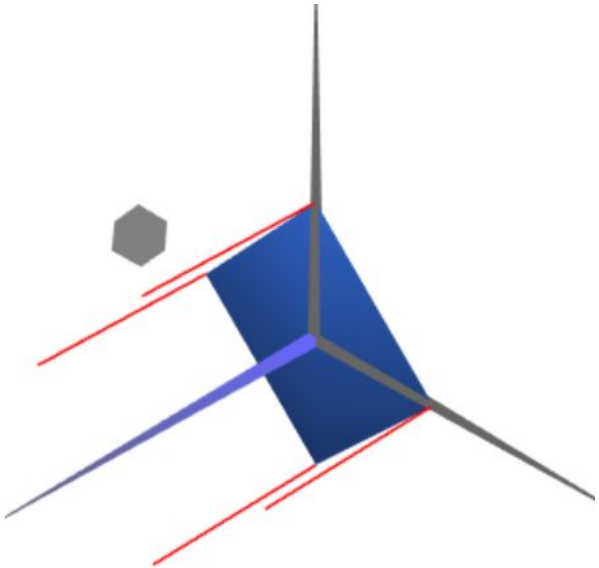
We defined **normals** for more realistic lighting of the geometries

```
this.vertices = {...}

this.indices = {...}

this.normals = {
    nAx,nAy,nAz,
    nBx,nBy,nBz,
    nCx,nCy,nCz,
    nDx,nDy,nDz
}
```



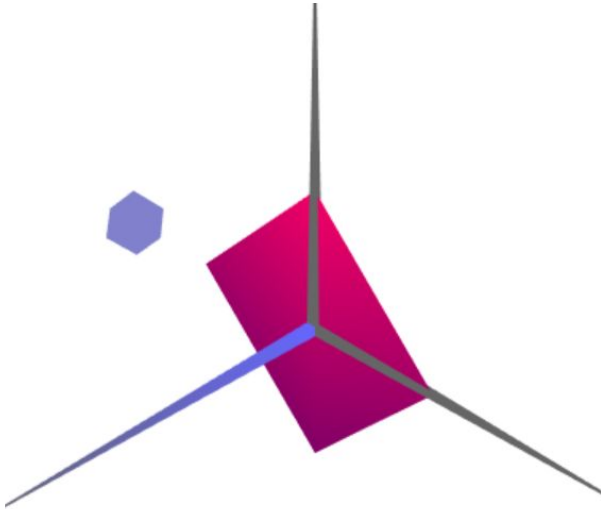


Previous lessons

We applied **materials** to change the appearance and color of the geometries

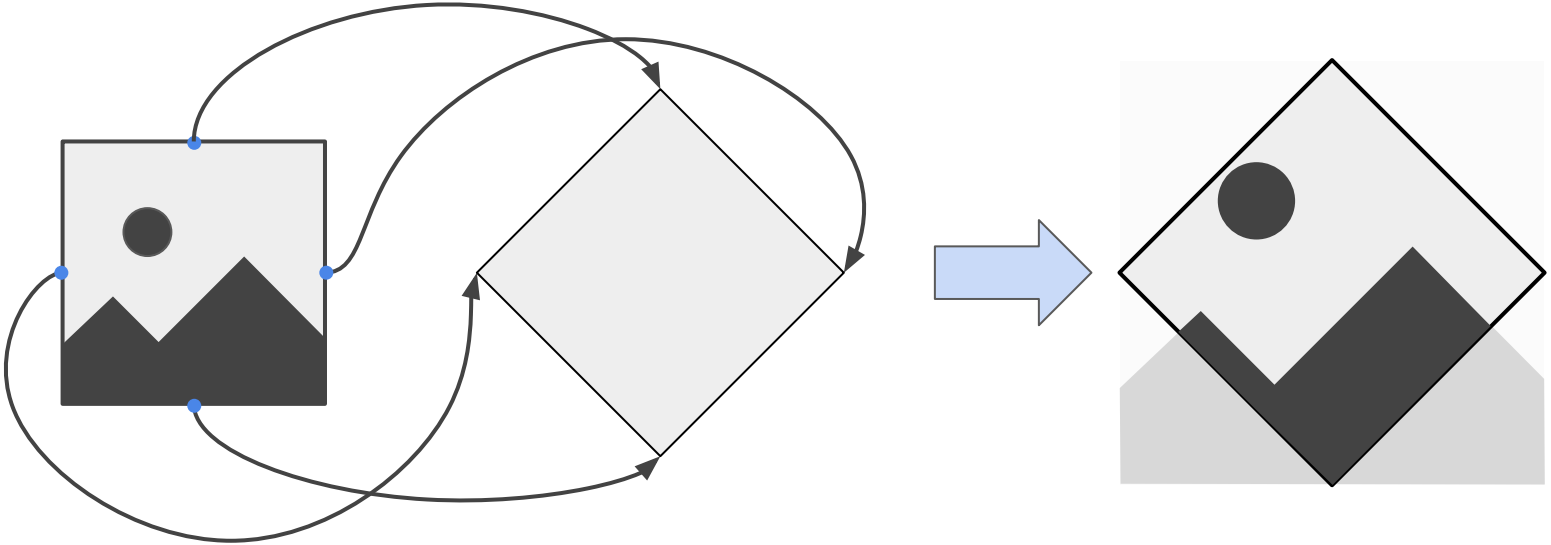
```
init(){
  ...
  this.material = new CGFappearance(scene)
}

display(){
  ...
  this.material.apply()
  this.object.display()
}
```



Application of textures

Another fundamental part of computer graphics - **textures**



Application of textures in WebGL

In **WebGL**, images can be loaded to be used as textures for the geometries.

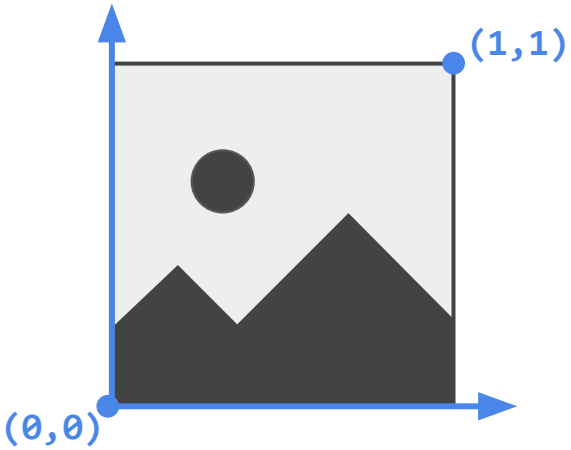
The process of **mapping a texture** to a geometry involves:

1. Define the **texture coordinates** for the geometry
2. **Load an image** into a texture
3. **Apply texture** before drawing geometry

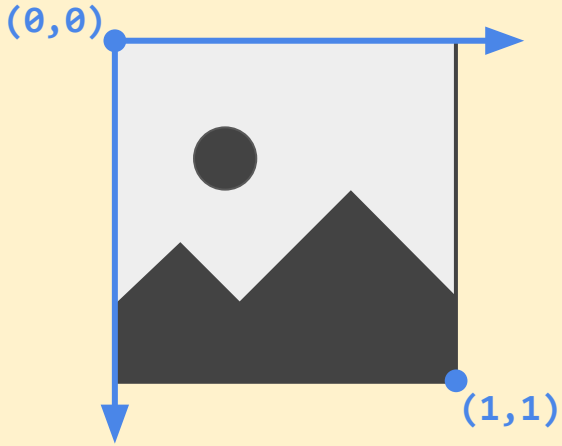
1 Texture coordinates

Textures use normalized `(u,v)` coordinates

A pair of `(u,v)` coordinates represents an **image pixel** (texel)



OpenGL UV coordinates



WebGL UV coordinates

1 Texture coordinates in WebGL/WebCGF

For each vertex of a geometry, a pair of texture coordinates is defined

In **object space**, texture coordinates are named **`(s,t)`**

The texture coordinates are defined in a ***texCoords*** array

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

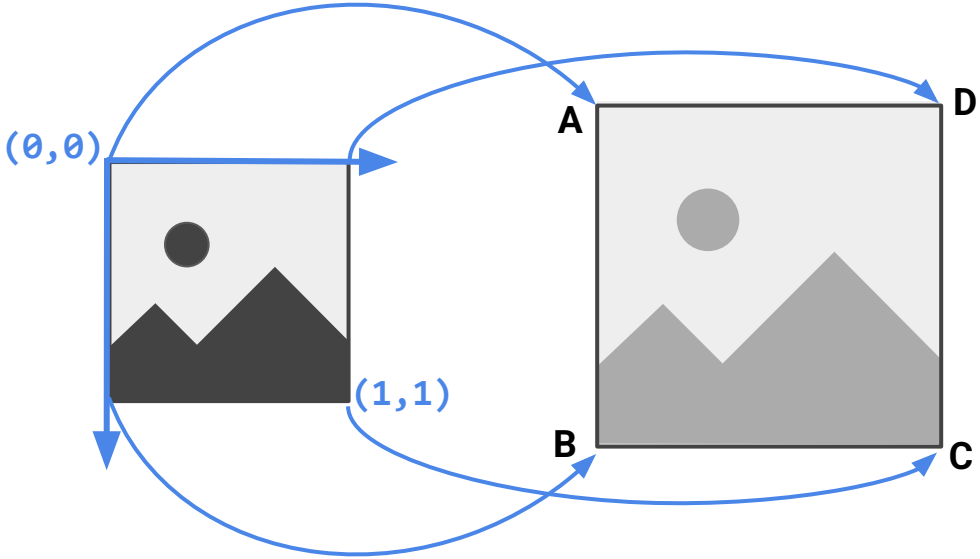
```
this.texCoords = {
    sA, tA,
    sB, tB,
    sC, tC,
    sD, tD
}
```

1 Texture coordinates - Example

Basic example: Mapping a square texture to a square object

```
this.vertices = {...}

this.texCoords = {
    0, 0, //A
    0, 1, //B
    1, 1, //C
    1, 0  //D
}
```

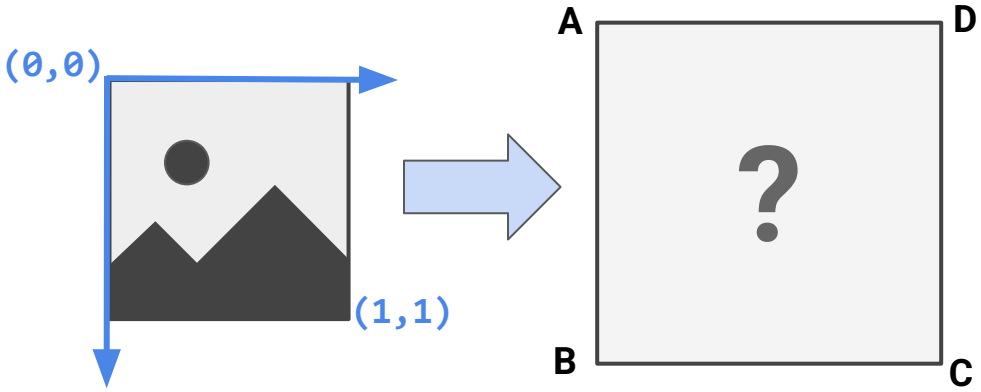


1 Texture coordinates - Example

Question: What happens when texture coordinates are out of [0-1] bounds?

```
this.vertices = {...}

this.texCoords = {
    0, 0, //A
    0, 1, //B
    2, 1, //C
    2, 0  //D
}
```



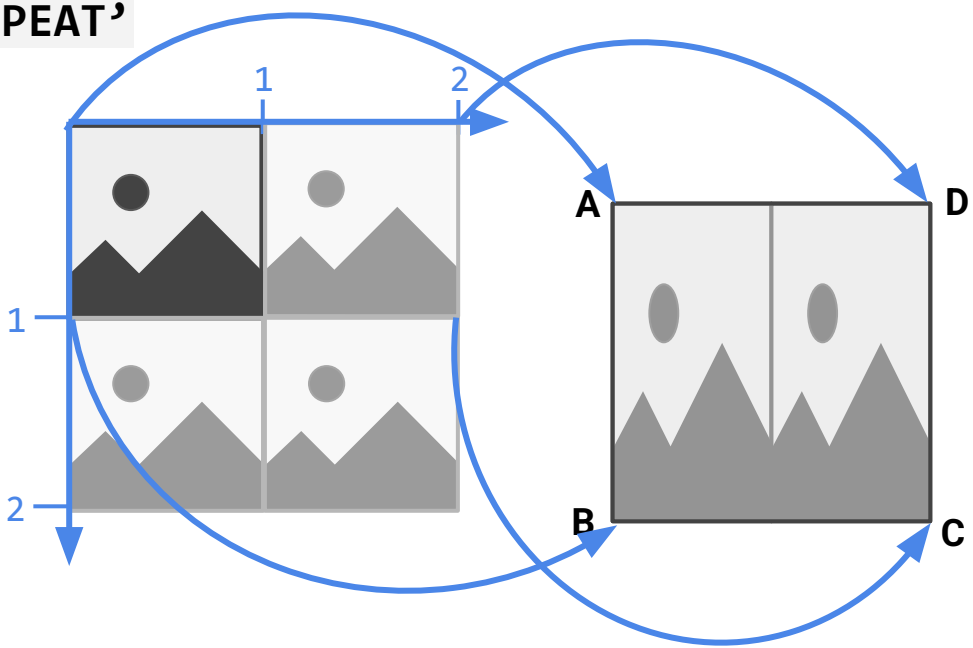
1 Texture coordinates - Wrap Mode

Defines how texture is sampled for coordinates out of [0-1] range

By default, wrap mode is `'REPEAT'`

```
this.vertices = {...}

this.texCoords = {
    0, 0, //A
    0, 1, //B
    2, 1, //C
    2, 0  //D
}
```

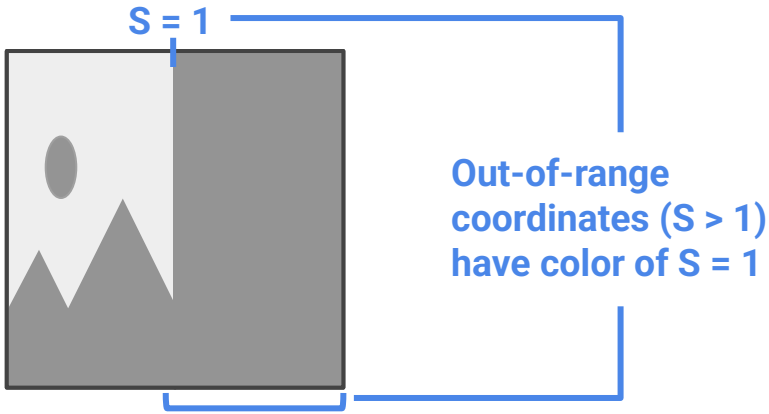


1 Texture coordinates - Wrap Mode

Wrap mode is applied to **each axis separately**

The other wrap modes are `'MIRRORED_REPEAT'` and `'CLAMP_TO_EDGE'`

`'MIRRORED_REPEAT'`
Texture is mirrored in S axis



`'CLAMP_TO_EDGE'`
Out-of-range coordinates copy margin values

2 Load image to texture with WebCGF

The **WebCGF** library has a class for textures - **CGFtexture**

```
new CGFtexture(scene, url)
```

Textures may be **associated to materials**

```
material.setTexture(CGFtexture)
```

Images may also be **loaded directly** to materials

```
CGFappearance.loadTexture(url)
```

3 Apply texture before drawing object

Textures may be applied in two different ways:

Indirectly, associating it to a material

```
material.setTexture(texture)
...
mat.apply()
object.display()
```

The **`CGFappearance`** class also provides a function to define **wrap mode**

```
setTextureWrap(wrapS, wrapT)
```

3 Apply texture before drawing object

Textures may be applied in two different ways:

Directly, by binding it to the WebGL context

```
texture.bind()
object.display()
```

This requires the use of WebGL functions to define **wrap mode**

```
gl.texParameter[fi](target, pname, param)
```

Documentation for texParameter function [link]

Additional texture parameters

Other texture parameters may be defined with `texParameter()` function

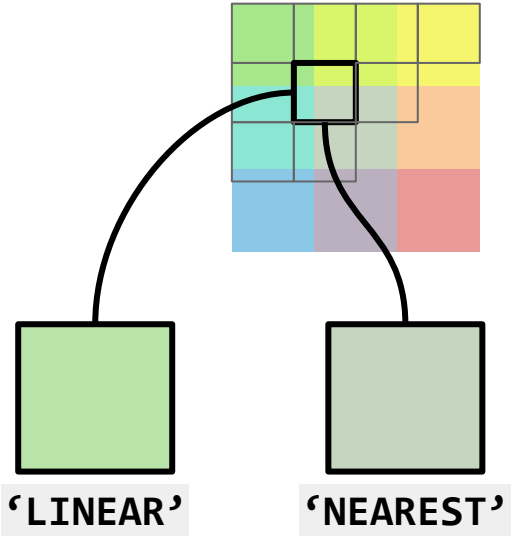
Texture filtering mode can be changed to adapt to current requirements

Example: Small texture and a large object

1+ pixel covers 1 texel (magnification)

Linear filtering blends colors of 4 closest texels

Nearest filtering uses color of closest texel



Documentation and guides

CGFtexture documentation

https://paginas.fe.up.pt/~ruirodrig/pub/sw/webcgf/docs/class/lib/CGF/CGFtexture.js~CGFtexture.html

CGFappearance documentation

https://paginas.fe.up.pt/~ruirodrig/pub/sw/webcgf/docs/class/lib/CGF/CGFappearance.js~CGFappearance.html

WebGL texture parameter function

https://developer.mozilla.org/en-US/docs/Web/API/WebGLRenderingContext/texParameter

WebGL textures tutorial

https://webglfundamentals.org/webgl/lessons/webgl-3d-textures.html

Texture wrap mode demonstrator

https://webglfundamentals.org/webgl/webgl-3d-textures-repeat-clamp.html