

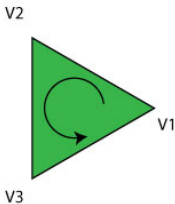
COMP220: Graphics & Simulation

4: Meshes

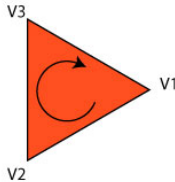
More complex meshes

Winding order

- ▶ It is sometimes important to know which side of a triangle is the “front” and which is the “back”
- ▶ OpenGL determines this by **winding order**



If the vertices go **anticlockwise**, you are looking at the **front**



If the vertices go **clockwise**, you are looking at the **back**

Backface culling

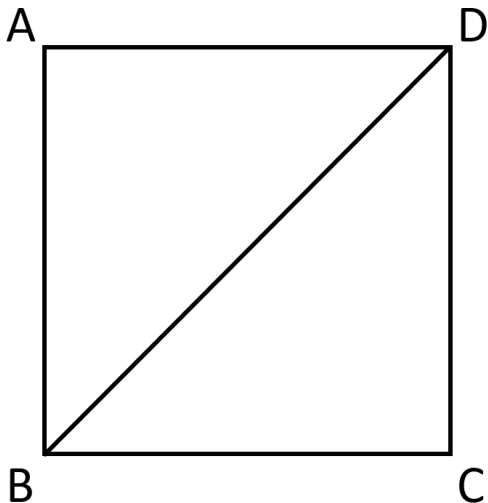
```
glEnable(GL_CULL_FACE);
```

- ▶ This will cause only the front faces of triangles to be drawn
- ▶ Triangles whose front face is not visible will be **culled**
- ▶ Culled faces are not passed through the rasteriser or fragment shader
- ▶ Saves time, and should make no difference to appearance — as long as all meshes are closed and have correct winding

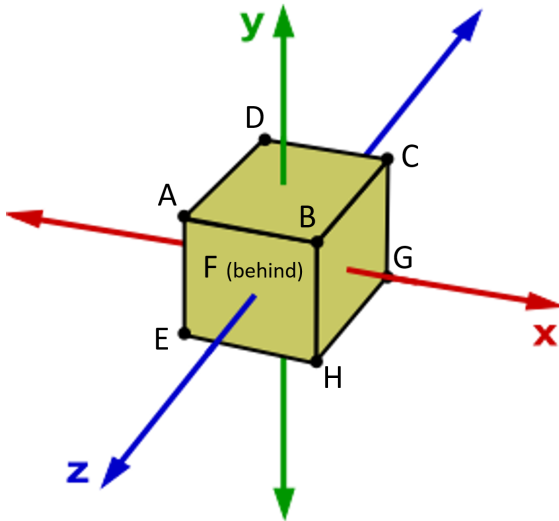
When backface culling goes bad?



Let's draw a square!



Let's draw a cube!



Vertices

Interleaved Vertices

- ▶ Up until this point we have been storing vertex positions as floats
- ▶ If we need a vertex to have colours, we can store these in a separate Vertex Buffer
- ▶ Or we can create a **C structure** which represents a Vertex, which has member variables which represent positions, colours, normals etc
- ▶ This is known as Interleaved Vertices and in **MOST** cases is more efficient

Vertex Structure 1

```
struct Vertex
{
    float x,y,z;
};

Vertex v[]={{-0.5f,-0.5f,0.0f},
            {0.5f,-0.5f,0.0f},
            {0.0f,0.5f,0.0f}};
```

Vertex Structure 2

```
struct Vertex
{
    float x,y,z;
    float r,g,b,a;
};

Vertex v[]={{-0.5f,-0.5f,0.0f,1.0f,0.0f,0.0f ←
            ,1.0f},
            {0.5f,-0.5f,0.0f,0.0f,1.0f,0.0f ←
            ,1.0f},
            {0.0f,0.5f,0.0f,0.0f,0.0f,1.0f,1.0 ←
            f}};
```

Changes to the Vertex Buffer

- ▶ There will be a slight change to our vertex buffer
- ▶ We have to take into account the size of the Vertex structure and the number of vertices in the buffer

Vertex Buffer Changes - Old version

```
glBufferData(GL_ARRAY_BUFFER, sizeof( ↵  
    g_vertex_buffer_data), ↵  
    g_vertex_buffer_data, GL_STATIC_DRAW);
```

Vertex Buffer Changes - new version

```
glBufferData(GL_ARRAY_BUFFER, 3* sizeof(Vertex ↔  
), v, GL_STATIC_DRAW);
```

Changes to the Vertex Array

- ▶ Since the layout of the vertices have changed in memory, we need to update the Vertex Array Object to reflect this
- ▶ Remember that the VAO describes the format of the vertices to the pipeline and enables the binding of vertex data to attributes in the shader

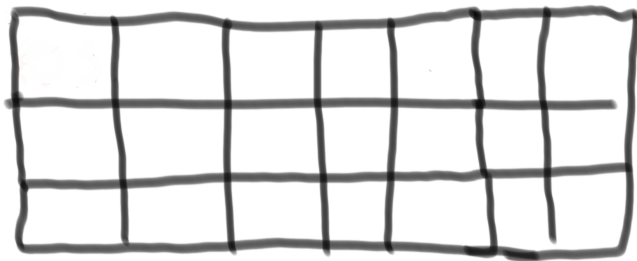
Vertex Array Object - Old version

```
glEnableVertexAttribArray(0);  
glVertexAttribPointer(0, 3, GL_FLOAT, GL_FALSE, 0, ( ←  
    void*) 0);
```


Vertex Array Object - New version

```
glEnableVertexAttribArray(0);  
glVertexAttribPointer(0, 3, GL_FLOAT, GL_FALSE, sizeof ↵  
    (Vertex), (void*) 0);  
  
glEnableVertexAttribArray(1);  
glVertexAttribPointer(1, 4, GL_FLOAT, GL_FALSE, sizeof ↵  
    (Vertex), (void*) (3*sizeof(float)));
```

Memory and Vertex Array Object 1



Memory and Vertex Array Object 2

-0.5	-0.5	0.0	1.0	0.0	0.0	1.0
0.5	-0.5	0.0	0.0	1.0	0.0	1.0
0.0	0.5	0.0	0.0	0.0	1.0	1.0

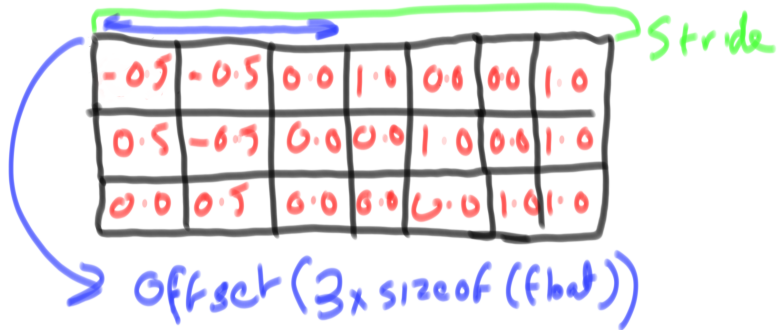
Memory and Vertex Array Object 3

- Stride



-0.5	-0.5	0.0	1.0	0.0	0.0	1.0
0.5	-0.5	0.0	0.0	1.0	0.0	1.0
0.0	0.5	0.0	0.0	0.0	1.0	1.0

Memory and Vertex Array Object 3 - Offset



Element Buffer

Element Buffer

- ▶ If we look at the cube sample, we are sending 36 vertices
- ▶ This is a bit wasteful considering that some of these vertices are duplicates
- ▶ We can use an **Element Buffer** to optimise our drawing
- ▶ An Element Buffer holds an integer which is an offset into a Vertex Buffer

Creating & Using Element Buffer

Live Coding

Exercise

- ▶ Finish off creating a cube using a Vertex Buffer
- ▶ Create a cube using an Element Buffer
- ▶ Create a function which fills a Vertex Buffer and Element Buffer for drawing a Sphere

Further Reading - Interleaved Vertices

- ▶ iOS Development Docs -
https://developer.apple.com/library/content/documentation/3DDrawing/Conceptual/OpenGL_ES_Programming_Guide/Techniques_for_Working_with_Vertex_Data/Techniques_for_Working_with_Vertex_Data.html
- ▶ To interleave or not to interleave - <https://anteru.net/blog/2016/02/14/3119/index.html>
- ▶ Vertex Specification Best Practices -
https://www.khronos.org/opengl/wiki/Vertex_Specification_Best_Practices

Further Reading - Element Buffer

- ▶ VBO indexing - <http://www.opengl-tutorial.org/intermediate-tutorials/tutorial-9-vbo-indexing/>
- ▶ Element Buffer - <https://goharsha.com/lwjgl-tutorial-series/element-buffer-objects/>