COMP3320 Introduction to OpenGL

Alex Biddulph

The University of Newcastle, Australia

Based on the work provided at `www.learnopengl.com`

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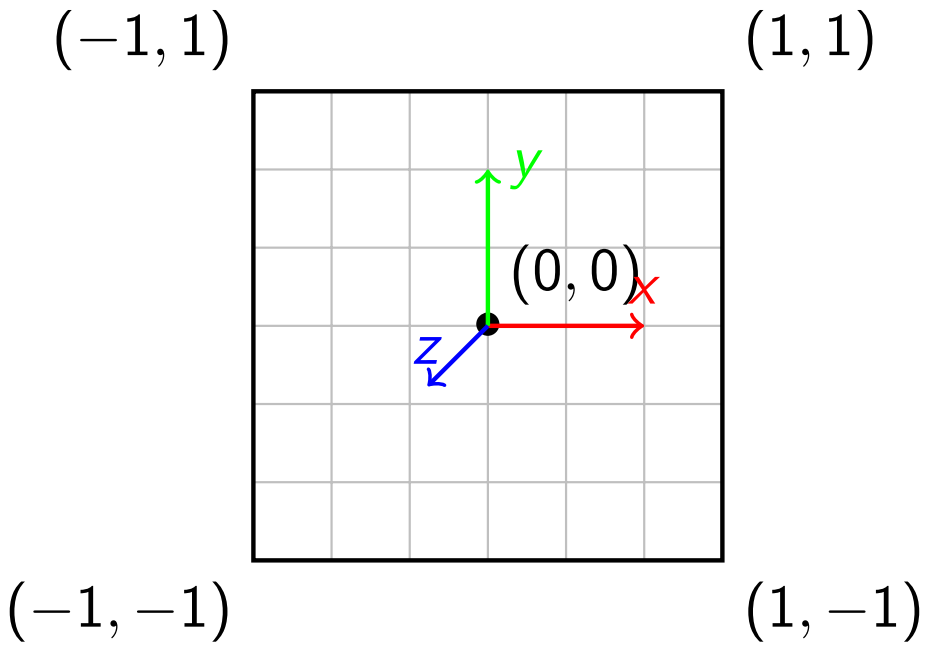
OpenGL Coordinates

- OpenGL uses a right-handed coordinate system
- OpenGL uses normalised device coordinates
- OpenGL will map the normalised device coordinates to the viewport dimensions
  - $(-1, -1) \rightarrow (0, 0)$
  - $(1, 1) \rightarrow (800, 600)$



OpenGL Coordinate Spaces

- Local Space: 3D coordinates which are local to an object
- World Space: 3D coordinates within the world. The model matrix is used to transform coordinates from local space to world space
- View Space: Also known as camera space or eye space. View space is the camera's perspective of your world. The view matrix is used to transform coordinates from world space to view space
- Clip Space: A projection from view space to normalised device coordinates. The projection matrix is used to perform this projection. OpenGL expects the output of the vertex shader to be in clip space

OpenGL Shaders - Pipeline 1

- Vertex Data: A list of 3D vertex coordinates and associated vertex attributes (we will come back to these later)
- Vertex Shader: Transforms vertex coordinates from model space to clip space
- Shape Assembly: Assembles transformed vertices into a given primitive shape (e.g. triangles)
- Geometry Shader: Transforms shape geometry by emitting new vertices
- Rasterization: Maps primitives to pixel space and creates fragments
- Fragment Shader: Calculates the final colour for a fragment
- Tests and Blending: Performs depth testing and alpha blending

OpenGL Shaders - Pipeline 2

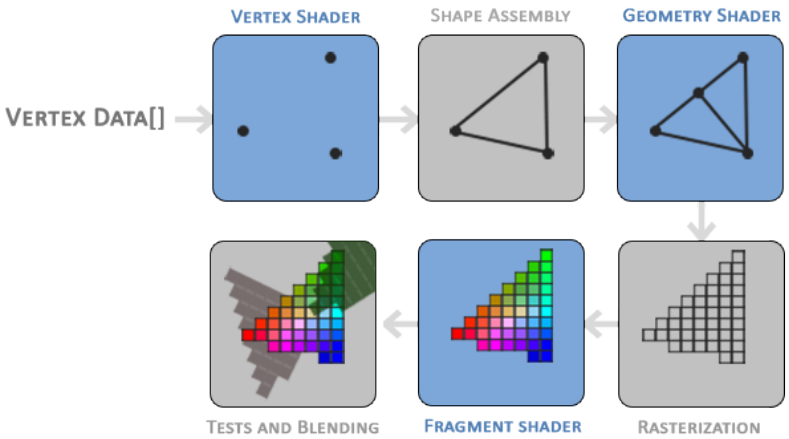


Figure: Graphics pipeline stages.

Image sourced from
`learnopengl.com/Getting-started/Hello-Triangle`

OpenGL Shaders

- Written in OpenGL Shader Language (GLSL)
- A simple vertex shader

```
#version 330 core
layout (location = 0) in vec3 aPosition;
void main() { gl_Position = vec4(aPosition, 1.0); }
```

- A simple fragment shader

```
#version 330 core
layout (location = 0) out vec4 FragColour;
void main() {FragColour = vec4(1.0f, 0.5f, 0.2f, 1.0f);}
```

Useful Functions for Shaders

Examples

Create a shader using ☞ `glCreateShader`

Examples

Attach shader source code using ☞ `glShaderSource`

Examples

Compile a shader using ☞ `glCompileShader`

OpenGL Shader Programs

- Consists of multiple OpenGL shaders
  - If you have a vertex shader, you must have a fragment shader
  - If you have a fragment shader, you must have a vertex shader
  - Geometry shader is optional
- **Vertex Shader:** Processes vertex data. Transforms model space coordinates to clip space coordinates
- **Geometry Shader:** Processes geometric primitive data. Modifies individual vertices in a primitive, either by moving the vertices or adding/deleting vertices
- **Fragment Shader:** Processes fragment data. Calculates lighting conditions for each fragment and assigns the final fragment colour

Useful Functions for Shader Programs

Examples

Create a shader program using ☞ `glCreateProgram`

Examples

Attach shaders to the program using ☞ `glAttachShader`

Examples

Link attached shaders together into the final program using ☞ `glLinkProgram`

Examples

Make a shader program active by using ☞ `glUseProgram`

Vertex Buffer Objects

- Stores vertex data in GPU memory
- Program could consist of multiple different vertex buffers
- Vertex data is defined as a list of 3D coordinates

```
float vertices[] = {-0.5f, -0.5f, 0.0f,
                     0.5f, -0.5f, 0.0f,
                     0.0f,  0.5f, 0.0f };
```

Examples

To create a vertex buffer use ☞ glGenBuffers

Examples

To make a vertex buffer active use ☞ glBindBuffer

Examples

To copy vertex data to GPU memory use ☞ glBufferData

Vertex Array Objects

- Manages vertex buffer objects and vertex attributes
- Program could consist of multiple different vertex arrays
- Bind and configure vertex buffer objects after binding the vertex array

Examples

To create a vertex array use ☞ `glGenVertexArrays`

Examples

To make a vertex array active use ☞ `glBindVertexArray`

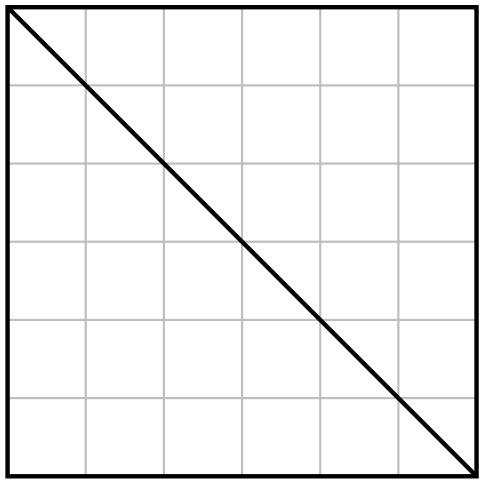
Examples

To render a vertex array use ☞ `glDrawArrays` or some other OpenGL drawing command after binding it

Element Buffer Objects

- Stores indexes into the list of vertex data
- Makes it easy to draw shapes which share vertices
  - An easy example is a square, which contains 2 triangles

$(-0.5, 0.5)$ $(0.5, 0.5)$



$(-0.5, -0.5)$ $(0.5, -0.5)$

  - The naive way to draw this square would be to draw two triangles by specifying six vertices. Two of the vertices would be repeated
  - The better way would be to list the four vertices in the square and use an element buffer object

Element Buffer Objects

- Program could consist of multiple different element buffers
- Element data is defined as a list of integer indices

```
float vertices[] = {-0.5f, -0.5f, 0.0f,
                     0.5f, -0.5f, 0.0f,
                     0.5f,  0.5f, 0.0f,
                    -0.5f,  0.5f, 0.0f };
unsigned int indices[] = {0, 1, 3,
                          1, 2, 3 };
```

- Vertex arrays will also track element buffers

Usefule Functions for Element Buffer Objects

Examples

To create an element buffer use ☞ `glGenBuffers`

Examples

To make an element buffer active use ☞ `glBindBuffer`

Examples

To copy index data to GPU memory use ☞ `glBufferData`

Examples

To render the data the data referenced by the element buffer use ☞ `glDrawElements`