Computer Graphics

3 - Lab - Sending Data to Shaders

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Outline

- Sending Data using Outs and Ins (Shader → Shader)
- Sending Data by Specifying Vertex Attributes (Application → Shader)
- Sending Data using Uniforms (Application → Shader)

Sending Data using Outs and Ins (Shader → Shader)

Recall: Vertex Shader

- Input: Per-vertex attributes (from CPU)
  - Position
  - Possibly any other per-vertex attribute such as color, normal, texture coordinates, …

- Output:
  - Vertex position *in clip space* (to vertex post-processing)
  - Possibly **any other per-vertex output** such as vertex color, vertex normal, … **(to fragment shader)**

- (We will look at the gray part later.)

Recall: Fragment Shader

- Input: Interpolated **vertex shader outputs**
  - **To "link"** vertex shader output and fragment shader input, **they must have the same type and name**.
  - Fragment shader input is **interpolated** vertex shader output at the fragment location.
- Output: Only one output, fragment color
- (We will look at the gray part later.)

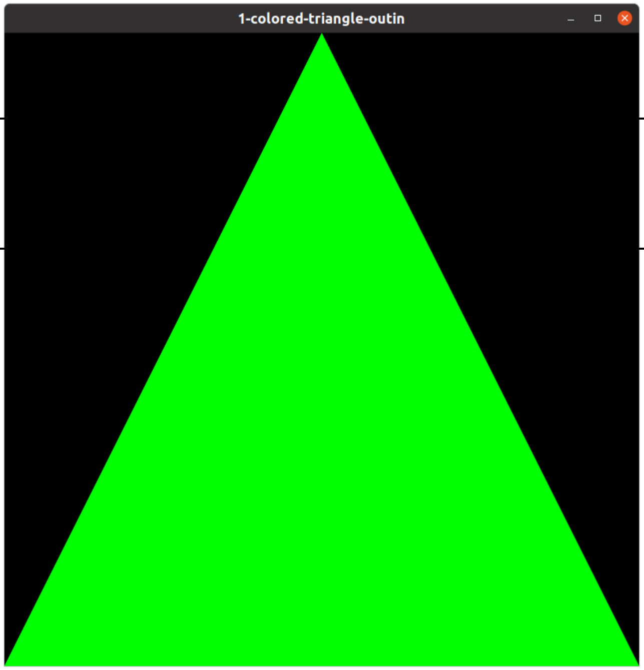
[Code] 1-colored-triangle-outin

Vertex shader

```
#version 330 core
layout (location = 0) in vec3 vin_pos;
out vec4 vout_color;
void main()
{
    gl_Position = vec4(vin_pos.x, vin_pos.y, vin_pos.z, 1.0);
    vout_color = vec4(0,1,0,1);
}
```

Fragment shader

```
#version 330 core
in vec4 vout_color;
out vec4 FragColor;
void main()
{
    FragColor = vout_color;
}
```



* The full source code can be found at https://github.com/yssl/CSE4020

Sending Data by Specifying Vertex Attributes (Application → Shader)

Specifying Vertex Attributes

- This is what we have covered in the previous lab.
  - Specifying vertex positions

- Here, we'll add one more per-vertex attribute – vertex color.

Add More Vertex Attributes

- Vertex input data so far (vertex positions only):

```
vertices = glm.array(glm.float32,
        -1.0, -1.0, 0.0, // left vertex
         1.0, -1.0, 0.0, // right vertex
         0.0,  1.0, 0.0  // top vertex
    )
```

- Add per-vertex color:

```
vertices = glm.array(glm.float32,
        # position          # color
        -1.0, -1.0, 0.0,  1.0, 0.0, 0.0, # left vertex
         1.0, -1.0, 0.0,  0.0, 1.0, 0.0, # right vertex
         0.0,  1.0, 0.0,  0.0, 0.0, 1.0, # top vertex
    )
```

Changes in Vertex Shader

- Let's set vertex attribute indexes as follows:
  - Vertex position: 0
  - Vertex color: 1

```
#version 330 core

layout (location = 0) in vec3 vin_pos;
layout (location = 1) in vec3 vin_color;

out vec4 vout_color;

void main()
{
    gl_Position = vec4(vin_pos.x, vin_pos.y, vin_pos.z, 1.0);
    vout_color = vec4(vin_color,1); // you can pass a vec3
and a scalar to vec4 constructor
}
```

Changes in Vertex Shader

- The fragment shader is the same.

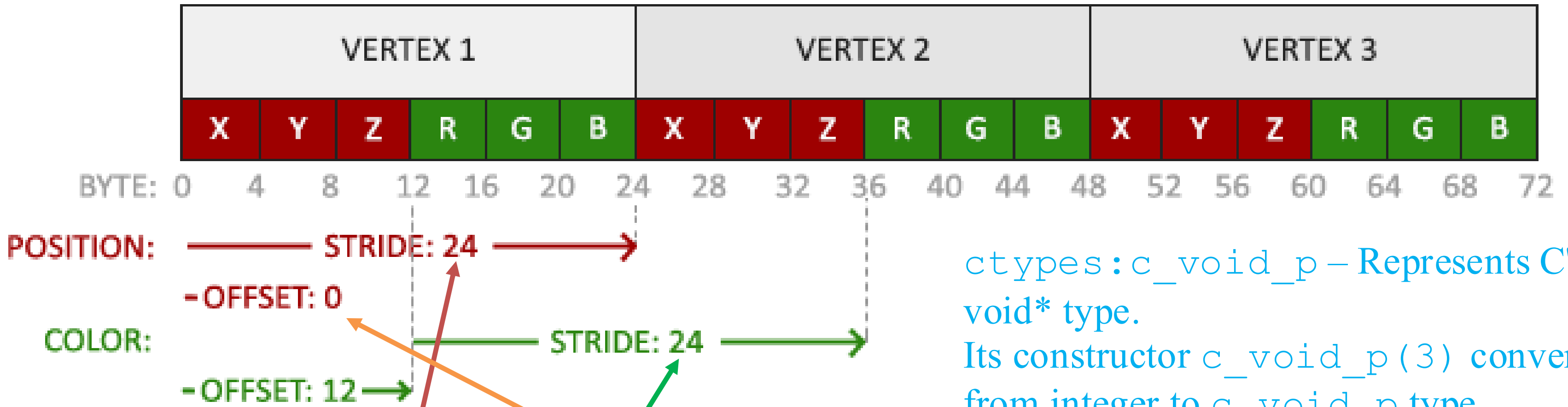
```
#version 330 core

in vec4 vout_color;

out vec4 FragColor;

void main()
{
    FragColor = vout_color;
}
```

Changes in Attributes Configuration


VERTEX 1
VERTEX 2
VERTEX 3
X Y Z R G B X Y Z R G B X Y Z R G B
BYTE: 0 4 8 12 16 20 24 28 32 36 40 44 48 52 56 60 64 68 72
POSITION:
STRIDE: 24
-OFFSET: 0
COLOR:
STRIDE: 24
-OFFSET: 12

ctypes:c_void_p – Represents C's void* type.
Its constructor c_void_p(3) converts 3 from integer to c_void_p type.

```
# configure vertex positions - index 0
glVertexAttribPointer(0, 3, GL_FLOAT, GL_FALSE,
6*glm.sizeof(glm.float32), None)
glEnableVertexAttribArray(0)

# configure vertex colors - index 1
glVertexAttribPointer(1, 3, GL_FLOAT, GL_FALSE,
6*glm.sizeof(glm.float32),
ctypes.c_void_p(3*glm.sizeof(glm.float32)))
glEnableVertexAttribArray(1)
```

* The image is from https://learnopengl.com/Getting-started/Shaders

[Code] 2-interpolated-triangle

- Vertex input data

```
vertices = glm.array(glm.float32,
        # position        # color
        -1.0, -1.0, 0.0,  1.0, 0.0, 0.0, # left vertex
         1.0, -1.0, 0.0,  0.0, 1.0, 0.0, # right vertex
         0.0,  1.0, 0.0,  0.0, 0.0, 1.0, # top vertex
    )
```

- Vertex shader

```
#version 330 core
layout (location = 0) in vec3 vin_pos;
layout (location = 1) in vec3 vin_color;
out vec4 vout_color;
void main()
{
    gl_Position = vec4(vin_pos.x, vin_pos.y, vin_pos.z, 1.0);
    vout_color = vec4(vin_color,1);
}
```

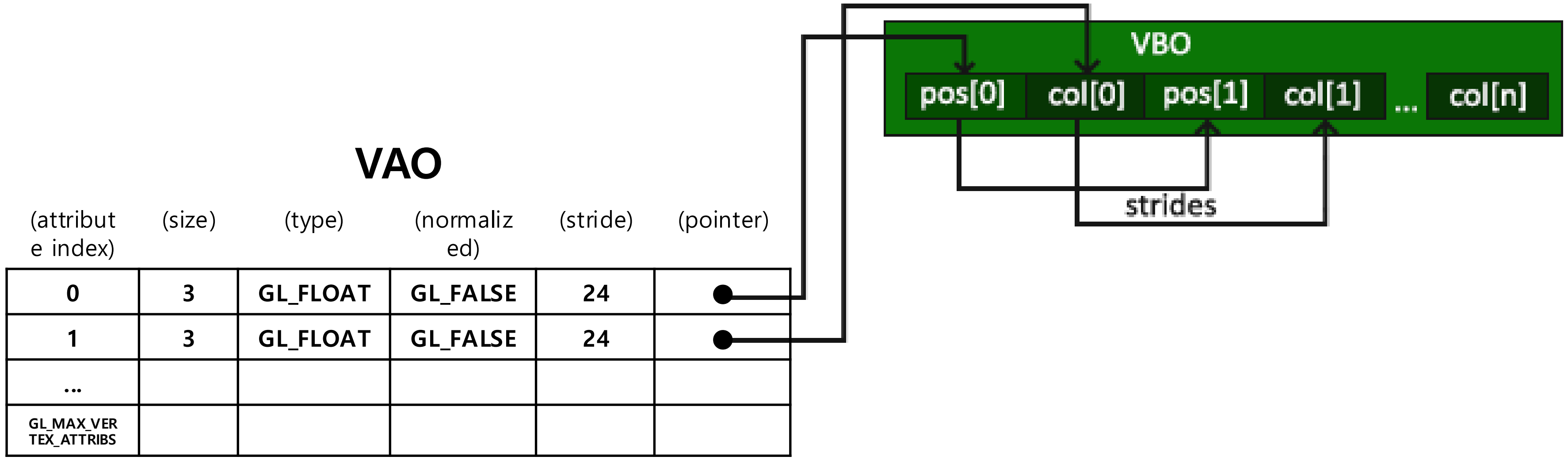
- Vertex attribute configuration

```
# configure vertex positions - index 0
glVertexAttribPointer(0, 3, GL_FLOAT, GL_FALSE, 6*glm.sizeof(glm.float32), None)
glEnableVertexAttribArray(0)

# configure vertex colors - index 1
glVertexAttribPointer(1, 3, GL_FLOAT, GL_FALSE, 6*glm.sizeof(glm.float32),
ctypes.c_void_p(3*glm.sizeof(glm.float32)))
glEnableVertexAttribArray(1)
```

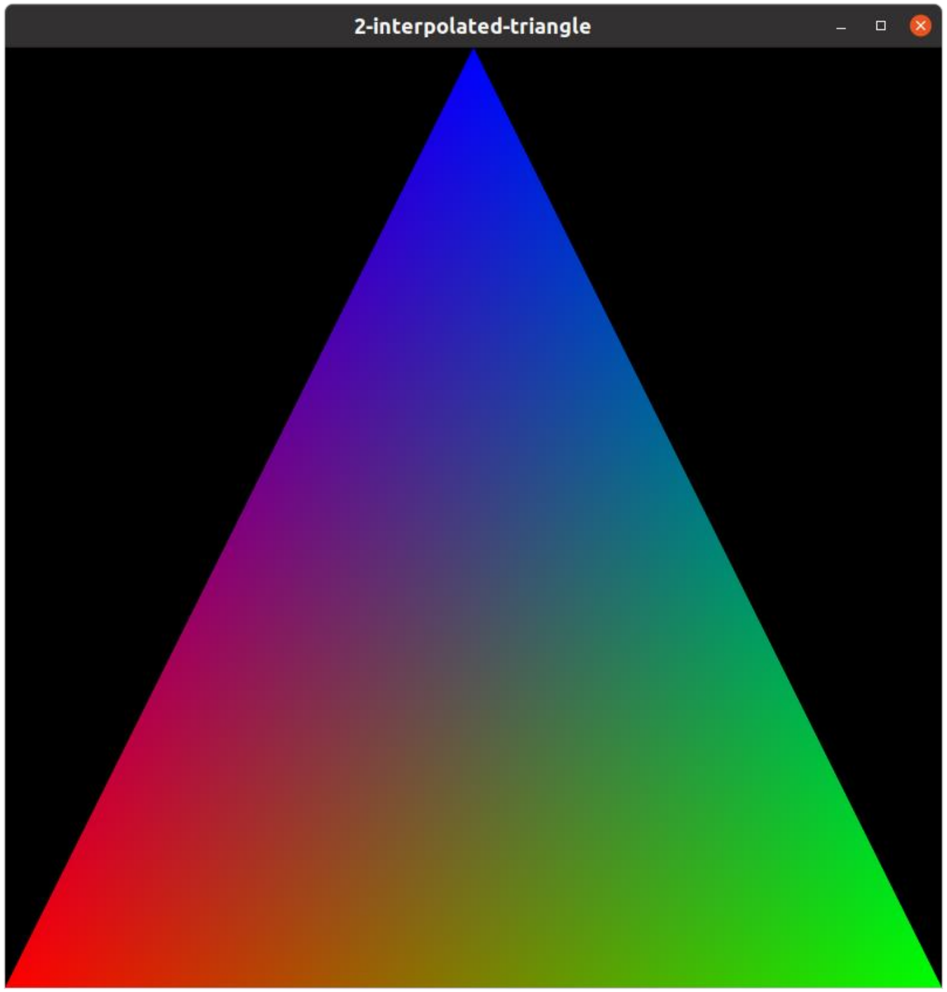
* The full source code can be found at https://github.com/yssl/CSE4020

VAO & VBO in this example



(attribut e index)	(size)	(type)	(normaliz ed)	(stride)	(pointer)
0	3	GL_FLOAT	GL_FALSE	24	●
1	3	GL_FLOAT	GL_FALSE	24	●
...					
GL_MAX_VERTEX_ATTRIBS					

[Code] 2-interpolated-triangle



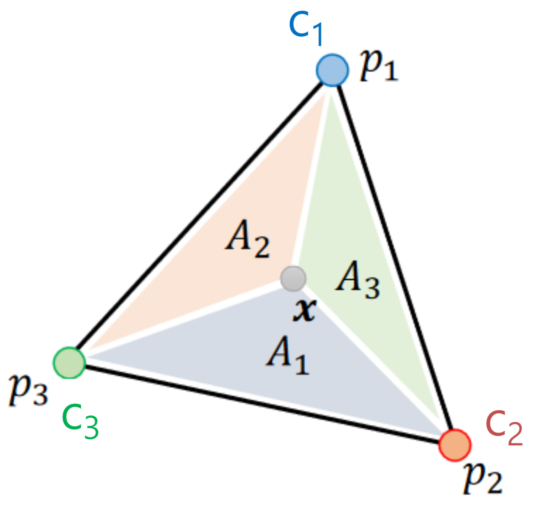
"Interpolated" Fragment Shader Inputs

- Input: **Interpolated** vertex shader outputs
  - To "link" vertex shader output and fragment shader input, they must have the same type and name.
  - Fragment shader input is **interpolated vertex shader output at the fragment location.**

- Output: Only one output, fragment color

Fragment Interpolation

- All the fragment shader's input are interpolated based on the positions of each fragments (where it resides on the triangle).
  - Barycentric interpolation

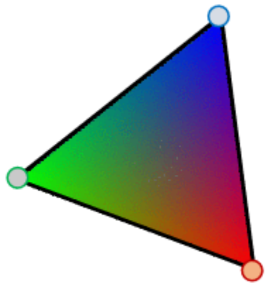


$\alpha_1 = {}^{A_1}/_{A}$	percentage blue c_1
$\alpha_2 = {}^{A_2}/_{A}$	percentage red c_2
$\alpha_3 = {}^{A_3}/_{A}$	percentage green c_3

A ... area of whole triangle

$$\mathbf{c_x} = \alpha_1 c_1 + \alpha_2 c_2 + \alpha_3 c_3$$

$$\alpha_1 + \alpha_2 + \alpha_3 = 1$$



* The image is from https://vis.uni-jena.de/Lecture/ComputerGraphics/Lec3_Shaders.pdf

Quiz 3

- Go to https://www.slido.com/
- Join #**cg-ys**
- Click "Polls"

- Submit your answer in the following format:
  - **Student ID: Your answer**
  - **e.g. 2021123456: 4.0**

- Note that your quiz answer must be submitted **in the above format** to be counted as attendance.

Sending Data using Uniforms (Application → Shader)

Uniform

- *Uniforms* are another way to send data from an application to shaders.
  - Useful for setting values that may change every frame.

```
#version 330 core
out vec4 FragColor;
uniform vec3 u_color;
void main()
{
    FragColor = vec4(u_color, 1.0);
}
```

- Uniform is unique per shader program object.
- Uniforms are global – can be accessed from any shader in the same shader program object.
- Uniforms keep their values until reseted or updated.

Setting Uniform Value

- First, we need to find the "location" of the uniform in the shader program.

```
loc_u_color = glGetUniformLocation(shader_program, 'u_color')
# find uniform's location
```

- `glGetUniformLocation(program, name)`
  - Returns the location of a uniform.
  - `program`: the shader program object
  - `name`: the name of the uniform

Setting Uniform Value

- Once we get the uniform's location, we can update the uniform's value.

- Note that updating uniform require you to first **activate the shader program**.

```
glUseProgram(shader_program)    # updating uniform
require you to first activate the shader program

glUniform3f(loc_u_color, 0, 0, 1) # set uniform's value
```

glUniform*()

- : Specify the value of a uniform variable for the current program object.

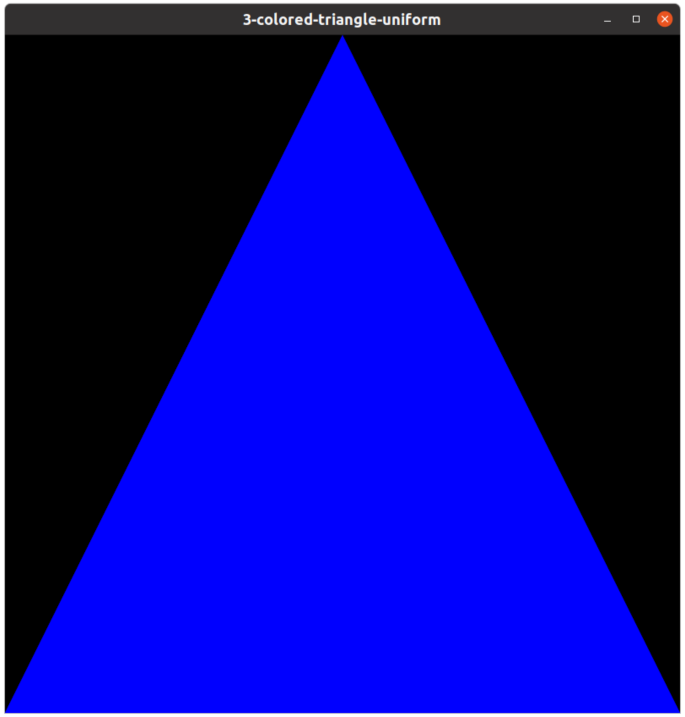
- Postfixes
  - f: the function expects a float as its value.
  - i: the function expects an int as its value.
  - ui: the function expects an unsigned int as its value.
  - 3f: the function expects 3 floats as its value.
  - fv: the function expects a float vector/array as its value.

- e.g. `glUniform4f()` takes 4 floats after the uniform's location as arguments.

[Code] 3-colored-triangle-uniform

- Fragment shader

```
#version 330 core
out vec4 FragColor;
uniform vec3 u_color;
void main()
{
    FragColor = vec4(u_color, 1.0);
}
```



- Setting Uniform Value

```
loc_u_color = glGetUniformLocation(shader_program,
'u_color') # find uniform's location
glUseProgram(shader_program)    # updating uniform
require you to first activate the shader program
glUniform3f(loc_u_color, 0, 0, 1) # set uniform's value
```

* The full source code can be found at https://github.com/yssl/CSE4020

For Animation

- For animation, we need to update uniforms every frame.
- Get uniform locations at initialization.
- Update uniforms in the rendering loop.

```
glGetUniformLocation

while:
    glUseProgram
    glUniform*

    glBindVertexArray(VAO)
    glDrawArrays
```

[Code] 4-color-changing-triangle

```
...
def main():
    ...
    # load shaders
    shader_program = load_shaders(g_vertex_shader_src, 
g_fragment_shader_src)

    # get uniform locations
    loc_u_color = glGetUniformLocation(shader_program, 
'u_color')
    ...
    # loop until the user closes the window
    while not glfwWindowShouldClose(window):
        ...
        glUseProgram(shader_program)

        # update uniforms
        t = glfwGetTime()
        blue = (glm.sin(t) + 1) * .5
        glUniform3f(loc_u_color, 0, 0, blue)
        ...
```

* The full source code can be found at https://github.com/yssl/CSE4020

Time for Assignment

- Let's start today's assignment.
- TA will guide you.