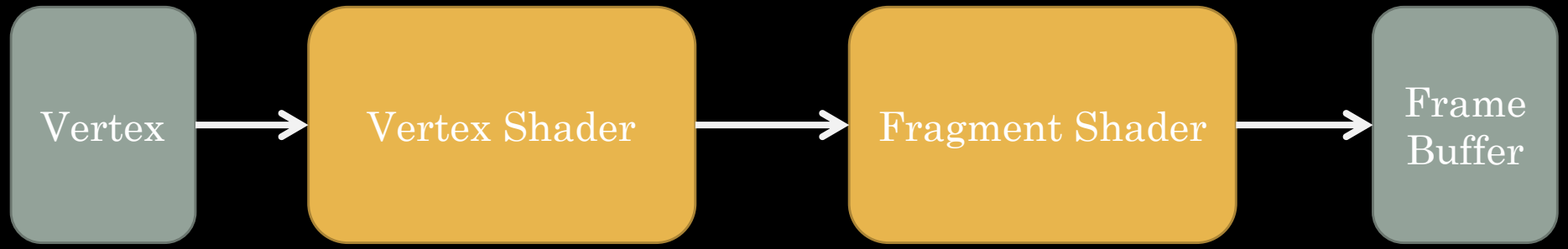
# HW2

# Shader

- A program designed by user
- Runs in GPU




Input: A vertex
Output: A vertex

Input: A pixel
Output: Pixel value

# Use Shader

- First, create shader
  - GLint glCreateShader(GLenum shaderType)
    - Create a shader object with specified shader type
    - shaderType : GL_VERTEX_SHADER, GL_FRAGMENT_SHADER in this homework
  - void glShaderSource(GLint shader, GLsizei count,
    const GLchar **string, const GLint *length)
    - Set the source code if shader to string
  - void glCompileShader(GLint shader)
    - Compile the shader

# Use Shader

- Then, create shader program
  - GLuint glCreateProgram()
    - Create a program object
  - void glAttachShader(GLuint program, GLuint shader)
    - Attach shader to program
  - void glLinkProgram(GLuint program)
    - Link the program
  - void glDeleteShader(GLunit shader)
    - Delete the shader after link

# Use Shader

```
while (!glfwWindowShouldClose(window))
{
        glUseProgram(program);
        // Pass parameters to shader program
        // Draw with the shader program
        glUseProgram(0);
        // Stop using program
        glUseProgram(another_program);
        // …
}
```

# VBO (Vertex Buffer Object)

- Passing data from CPU to CPU is relatively slow
- We can send a large amount of data to GPU at one time to speed up execution
- 1. void glGenBuffer(GLsizei n, GLuint *buffers)
  - Generate n buffer(s), stored in buffers

```
unsigned int VBO;
glGenBuffers(1, &VBO);
```

- 2. void glBindBuffer(GLenum target, GLuint buffer)
  - Bind buffer to target, which is GL_ARRAY_BUFFER in this homework

```
glBindBuffer(GL_ARRAY_BUFFER, VBO);
```

# VBO

- 3. Set up the data
- 4. void glBufferData(GLenum target, GLsizeptr size,
  const GLvoid *data, GLenum usage)
  - Copy the data into buffer

GL_STATIC_DRAW:
Data is set only once
and is used many times

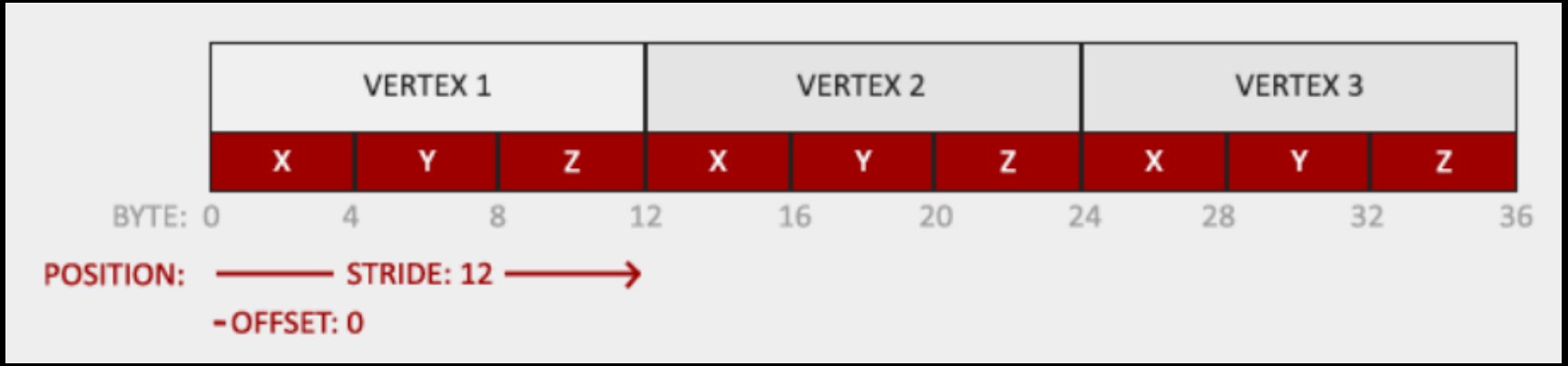
```
glBufferData(GL_ARRAY_BUFFER, sizeof(vertices), vertices, GL_STATIC_DRAW);
```

# Vertex Attribute Pointer

- We now need to specify how openGL interprets the data
- void glVertexAttribPointer(GLuint index, GLint size,
  GLenum type, GLboolean normalized, GLsizei stride,
  const GLvoid *pointer)
  - Index: sets the location of the vertex attribute
  - Size: the size of vertex attribute every vertex
  - Stride: the spacing between consecutive vertex attributes
  - Pointer: the offset where the data begins in the buffer
- void glEnableVertexAttribArray(GLuint index)
  - Enable the vertex attribute

# Vertex Attribute Pointer

- void glVertexAttribPointer(GLuint index, GLint size,
  GLenum type, GLboolean normalized, GLsizei stride,
  const GLvoid *pointer)

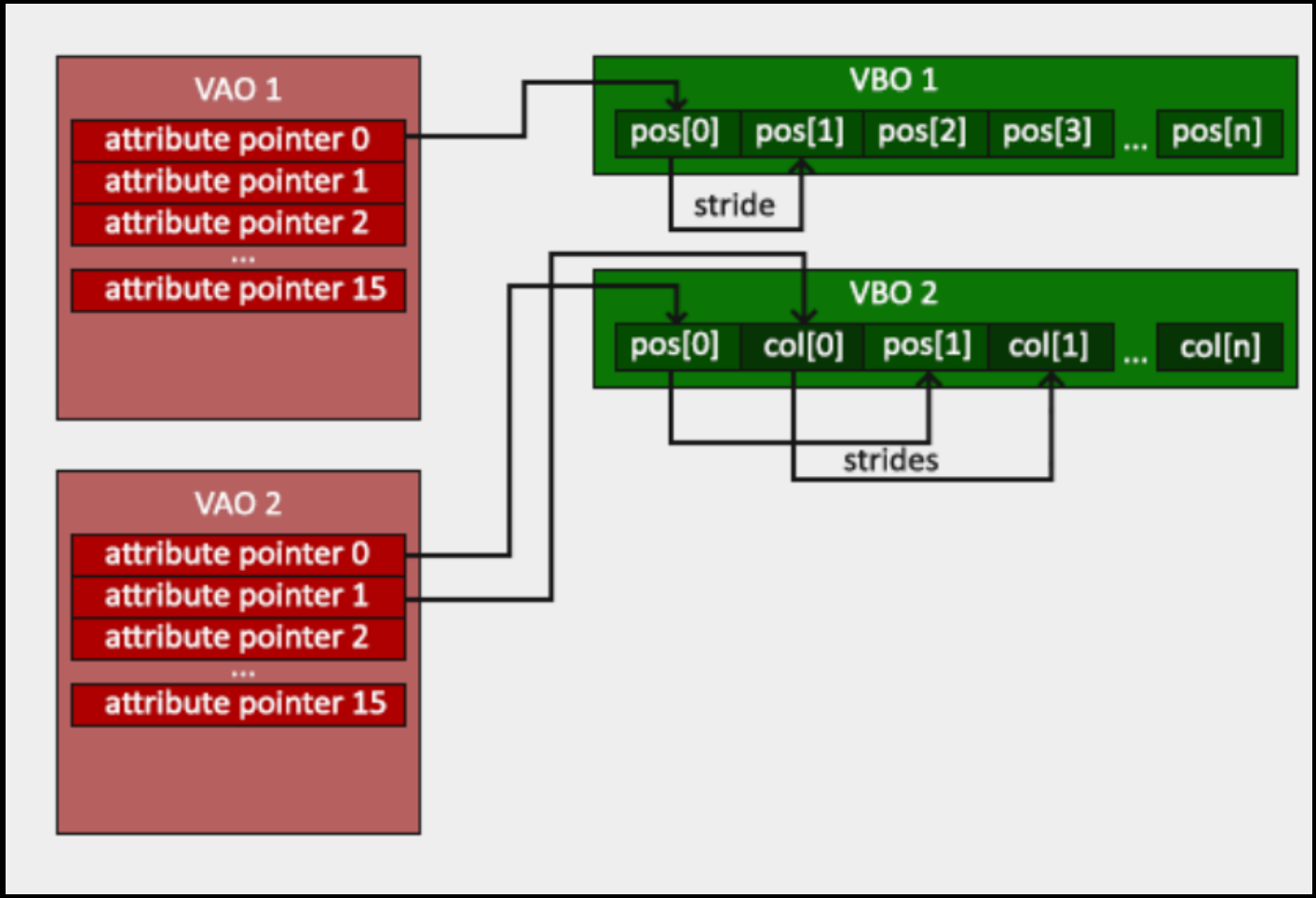



```
glVertexAttribPointer(0, 3, GL_FLOAT, GL_FALSE, 3 * sizeof(float), (void*)0);
glEnableVertexAttribArray(0);
```

# VAO (Vertex Array Object)

- A model may have multiple vertex attribute pointer
- We can use a VAO to store all vertex attribute pointer
- First, create a VAO and set up all its VBO and vertex attribute pointer. Then, simply bind the VAO to render the model.

# VAO (Vertex Array Object)



# VAO setup

- 1. void glGenVertexArrays(GLsizei n, GLuint *array)
  - Create VAO
- 2. void glBindVertexArray(GLuint array)
  - Bind a VAO
- 3. Set VBO and vertex attribute pointer up
- 4. Unbind VAO by glBindVertexArray(0)

# VAO setup

```
unsigned int VAO, VBO;
glGenVertexArrays(1, &VAO);
glBindVertexArray(VAO);
glGenBuffers(1, &VBO);

glBindBuffer(GL_ARRAY_BUFFER, VBO);
glBufferData(GL_ARRAY_BUFFER, sizeof(GL_FLOAT) * (model->positions.size()), &(model->positions[0]), GL_STATIC_DRAW);
glVertexAttribPointer(0, 3, GL_FLOAT, GL_FALSE, sizeof(GL_FLOAT) * 3, 0);
glEnableVertexAttribArray(0);
glBindBuffer(GL_ARRAY_BUFFER, 0);

glBindVertexArray(0);
```

# VAO during rendering

```
while (!glfwWindowShouldClose(window))
{
        // Bind the VAO of desired model
        glBindVertexArray(VAO);
        // Draw the model
        glDrawArrays(GL_TRIANGLES, 0, vertexCounts);
        // Unbind VAO after use
        glBindVertexArray(0);
}
```

# Send Data to shader - Uniform

In openGL:

```
glm::mat4 matrix(1.0f);
unsigned int loc = glGetUniformLocation(program, “matrix”);

glUseProgram(program);
glUniformMatrix4fv(loc, 1, GL_FALSE, glm::value_ptr(matrix));
```

In GLSL:

```
uniform mat4 matrix;
```

https://registry.khronos.org/OpenGL-Refpages/gl4/html/glUniform.xhtml

# GLSL

- C-like language for shaders

Version number

Input from vertex attribute pointer

Input from uniform

Output to fragment shader

```
// example vertex shader
#version 330 core

layout (location = 0) in vec3 position;

uniform vec4 color;

out vec4 vertexColor;

void main()
{
	gl_Position = vec4(position, 1.0f);
	vertexColor = color;
}
```

Must assign gl_Position of type vec4 in vertex shader

# GLSL

Interpolated input from vertex shader

Color output

```
// example fragment shader
#version 330 core

in vec4 vertexColor;

out vec4 fragColor;

void main()
{
	fragColor = vertexColor;
}
```

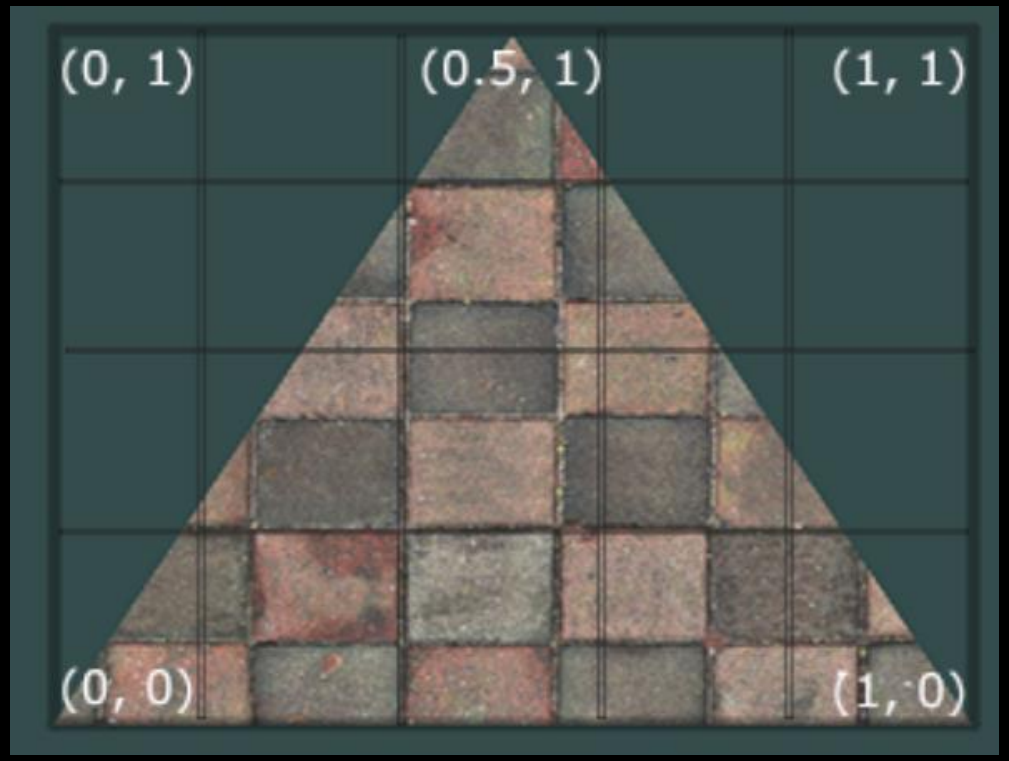
Must output a vec4 as color in fragment shader

# GLSL

- Variable type
  - vec2, vec3, vec4, …
  - int, float, bool, …
  - mat2, mat3, mat4, …
  - …
- Basic functions
  - min, max, sin, cos, pow, log, …
  - dot, normalize, …
  - transpose, reverse, …

# Texture

- A vertex is assigned with a texture coordinate
- Color is sampled with the texture coordinate



# Load Texture

- void glEnable(GL_TEXTURE_2D)
  - Enable 2D texture
- void glGenTexture(GLsizei n, GLuint *texture)
  - Generate a texture
- void glBindTexture(GLenum target, GLunit texture)
  - Bind texture so following call affect to bound texture
- void glTexImage2D(GLenum target, GLint level,
  GLint internalformat, GLsizei width, GLsizei height, GLint border, GLenum format, GLenum type, const void *data)
  - Generate 2D texture image with given image data

# Load Texture

- void glTexParameteri(GLenum target, GLenum pname, GLint param)
- Texture coordinates usually range from (0, 0) to (1, 1). We can define how to deal with coordinates outside [0, 1]. (default to GL_REPEAT)
  - glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_WRAP_S, GL_REPEAT)
  - glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_WRAP_S, GL_REPEAT)
- Texture coordinates are float point value regardless of resolution. We need to decide which texture pixel to map the texture coordinate to
  - glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_NEARSET)
  - glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_ MAG_FILTER , GL_LINEAR)

# Use Texture

```
// tell openGL which texture unit a sampler belong to
// texture unit 0 to ourTexture sampler
glUniform1i(glGetUniformLocation(, “ourTexture"), 0);
while (!glfwWindowShouldClose(window))
{
        glAvtiveTexture(GL_TEXTURE0);
        glBindTexture(GL_TEXTURE_2D, texture);
        // Draw with shader
}
```

You can pass more then one texture to shader.
In that case, you need to tell openGL which texture unit a texture sampler uses

# Use Texture in GLSL

```
// example texture fragment shader
#version 330 core

in vec4 vertexColor;
in vec2 texCoord;

uniform sampler2D ourTexture;

out vec4 fragColor;

void main()
{
	fragColor = texture(ourTexture, texCoord);
}
```

# HW2

- Goal: use GLSL to draw a cat and a box and apply some effect with shader
- Some parameters you may need:
  - model->positions
  - model->normals
  - model->texcoords

```
vector<float> positions;
vector<float> normals;
vector<float> texcoords;
```

- Box: scale (0.0625, 0.05, 0.05)
- Cat: rotate 90 degrees around +y axis
- Both rotate 90 degrees/second
  - Hint: glfwGetTime() return the time in second from initialization

# HW2 – special effect

- Effect 1: model deformation
  - Create deformation effect by changing vertices positions of the cat
  - Flattening, squeezing, …, you can do any effect you want
- Effect 2: change color
  - Change PART of the pixels color of the cat
  - For instance, you can use a threshold to find the strips of the cat and darken them
  - You can do any effect you want
- Both effects are initially off and are triggered by key press
- Tell us what you did and how to activate them in report

# HW2

# HW2 - score

- Basic shader program(10%)
- Set up VAO for cat and box (10% each)
- Set up texture for cat and box (10% each)
- Pass perspective, view, transform matrices, textures through uniform (10%)
  - Hint: getPerspective(), getView()
- Effects (10% each)
- Bonus (10%) – do anything you want without breaking the spec
  - Please have your bonus activated after pressing a key, so that we can judge your program without the bonus
  - Amazing deformation/color effect will also get bonus point!

# HW2 – report (20%)

- Include your name and student ID in the report
- Tell us how you do your homework
- Don’t paste your code without explanation
- Describe problems you met and how you solved them
- Explain your bonus and how to activate (optional)
- File name: studentID_report.pdf

# HW2 - submission

- Deadline: 2022/11/22 23:59:59
- Pack your project and report in a zip file. File name should be studentID_hw2.zip
- 10% penalty for each week late

# HW2 – reference

- https://learnopengl.com/
- https://www.glfw.org/docs/3.3/index.html