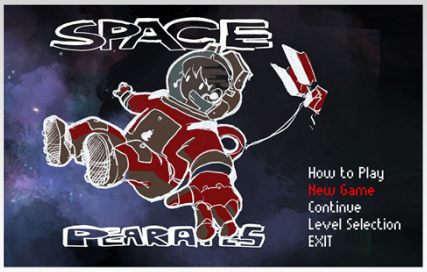
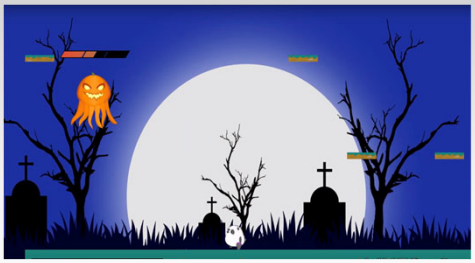
CPSC 427
Video Game Programming





Grading System

3%: Classroom Participation

- *Q & A*
- *Clickers*

TODOs

- Individual:
  - *Assignment 1 (individual)*
  - *Read through course pages*
  - *Register to Piazza*
- **!!!Team organizing!!!**

TODO: TEAM ORGANIZING

- Team organizing (use piazza to connect), seek common game ideas, diversity of experience
  - *Initial teams: Sep 11 – use the google doc to self-organize*
  - *Finalize by **Sep 18***
  - **We can help…**
- Game Pitch (storyline + basic technical elements) – individual/mini-team
  - *Informal piazza pitches: ASAP – helps with team building*
  - *Oral pitches: **Wednesday Sep 11***
    - Plan on ~1-2 minutes: game idea+team
    - Presentation order = Team order in google doc
  - *Written pitches: due **Sep 13***

Rendering Pipeline

Abstract model of

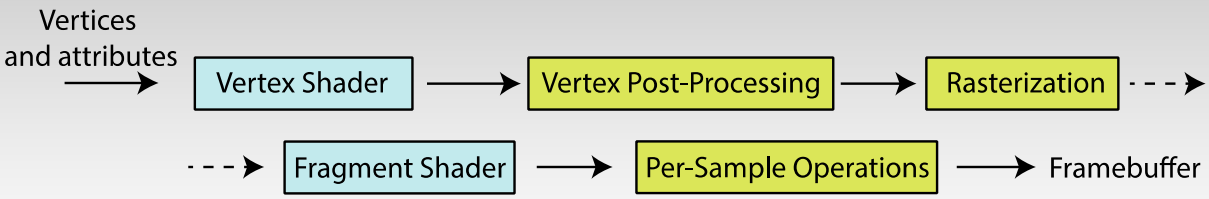
- sequence of operations to transform geometric model into digital image
- graphics hardware workflow

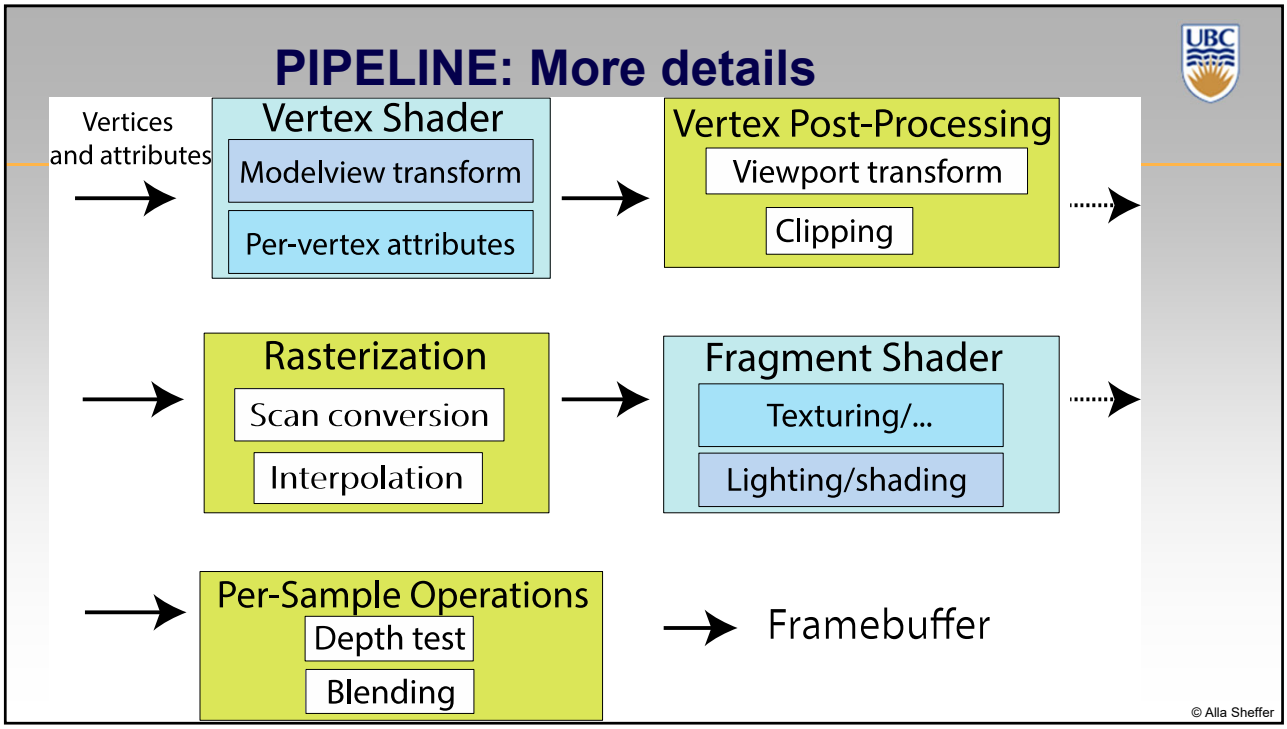
Underlying API (application programming interface) model for programming graphics hardware

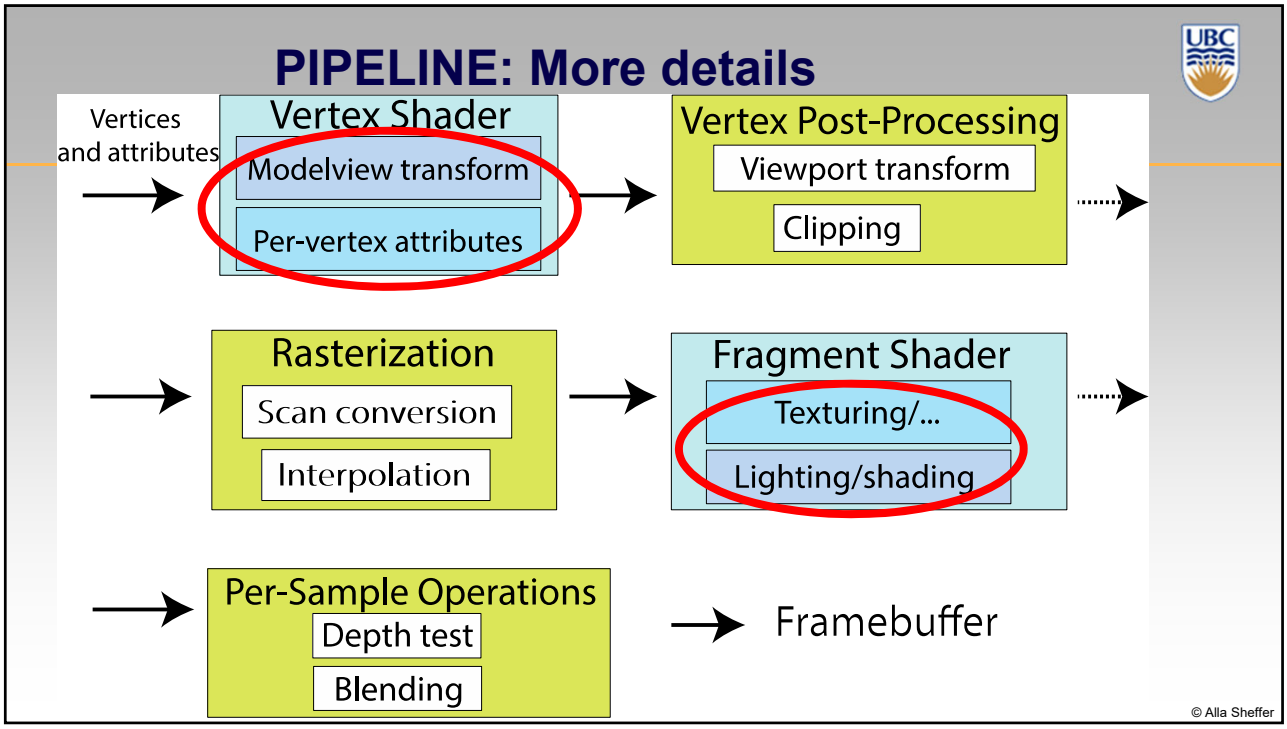
- OpenGL
- Direct 3D

Actual implementations vary

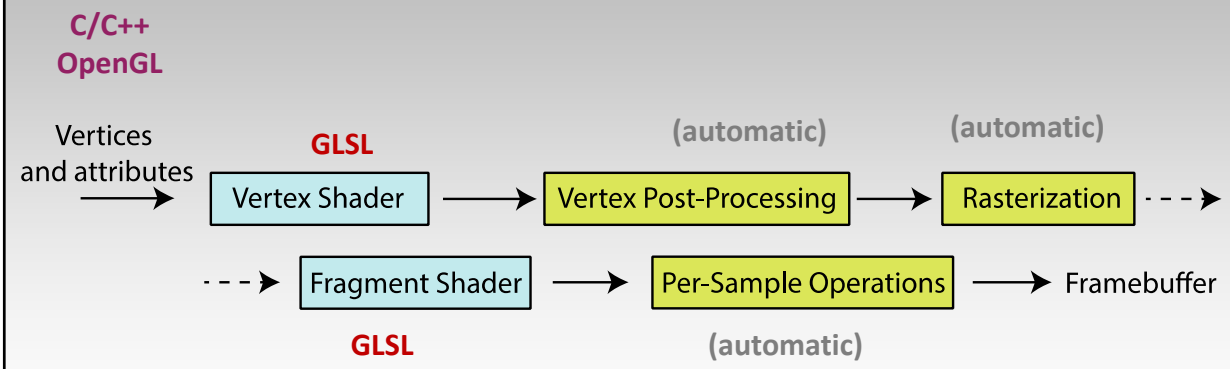
Opengl RENDERING PIPELINE




PIPELINE: More details
Vertices and attributes
Vertex Shader
Modelview transform
Per-vertex attributes
Vertex Post-Processing
Viewport transform
Clipping
Rasterization
Scan conversion
Interpolation
Fragment Shader
Texturing/...
Lighting/shading
Per-Sample Operations
Depth test
Blending
Framebuffer
© Alla Sheffer


PIPELINE: More details
Vertices and attributes
Vertex Shader
Modelview transform
Per-vertex attributes
Vertex Post-Processing
Viewport transform
Clipping
Rasterization
Scan conversion
Interpolation
Fragment Shader
Texturing/...
Lighting/shading
Per-Sample Operations
Depth test
Blending
Framebuffer
© Alla Sheffer

Opengl RENDERING PIPELINE



Event-Driven Programming

Main loop not under your control

- vs. procedural

Control flow through event callbacks

- redraw the window now
- key was pressed
- mouse moved

Callback functions called from main loop when events occur

- mouse/keyboard

Minimal Main

```
int main(int argc, char* argv[]) {
  if (!world.init(..)){
    return EXIT_FAILURE;
  }
  while (!world.is_over()) {
      glfwPollEvents(); // process events
      world.update(); // update game state based on events + timer
      world.draw(); // render
  }
  world.destroy();
  return EXIT_SUCCESS;
}
```


Even Callbacks

Set at start – in our template in world.init()

```
auto key_redirect = [](GLFWwindow* wnd, int _0, int _1, int _2, int _3) {
    ((World*)glfwGetWindowUserPointer(wnd))->on_key(wnd, _0, _1, _2, _3); };
auto cursor_pos_redirect = [](GLFWwindow* wnd, double _0, double _1) {
    ((World*)glfwGetWindowUserPointer(wnd))->on_mouse_move(wnd, _0, _1); };
glfwSetKeyCallback(m_window, key_redirect);
glfwSetCursorPosCallback(m_window, cursor_pos_redirect);
```

Another example would be a mouse click (same format)

Callback Actions

```
void World::on_key(GLFWwindow*, int key, int, int action, int mod){
if (action == GLFW_RELEASE && key == GLFW_KEY_R){
    …
}
if (action == GLFW_RELEASE && (mod & GLFW_MOD_SHIFT) &&  key ==
GLFW_KEY_COMMA){
 …
}
void World::on_mouse_move(GLFWwindow* window, double xpos, double
ypos){
}
```


openGL

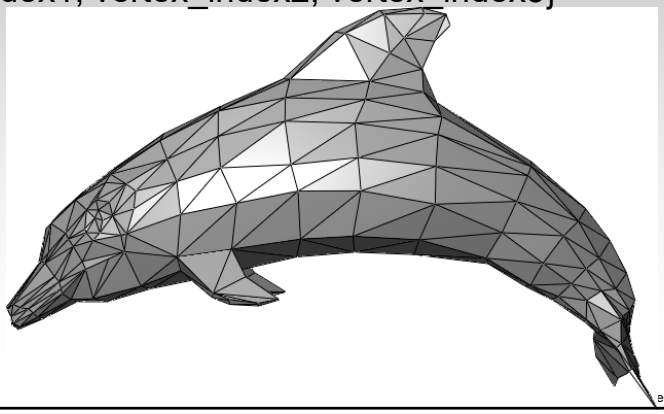
- Low-level graphics API
- C Interface accessed from C++

- Mesh: **Vertex Buffers** and **Index Buffers**
- Materials: **Shaders**, **Textures**, **Samplers** and **Uniforms**
- Camera: **(View)** and **(Projection)** matrices

GEOMETRY

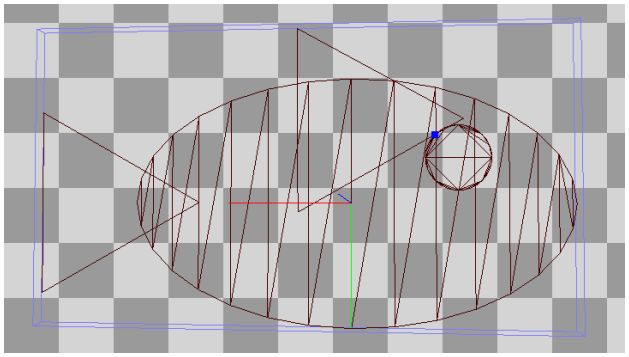
Triangle meshes

- Set of vertices
- Triangle defines as {vertex_index1, vertex_index2, vertex_index3}



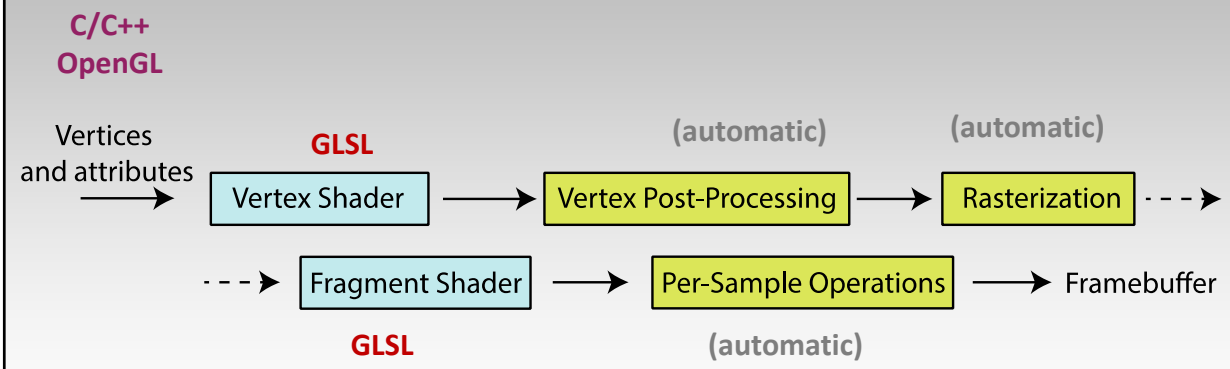
```
vertices[0].position = { -0.54, +1.34, -0.01 };
vertices[1].position = { +0.75, +1.21, -0.01 };
..
vertices[150].position = { -1.22, +3.59, -0.01 };

uint16_t indices[] = { 0, 3, 1,.. , 152, 150 };
Gluint ibo, vbo;
glGenBuffers(vbo);
glBindBuffer(vbo);
glBufferData(vbo, vertices);

glGenBuffers(ibo);
glBindBuffer(ibo);
glBufferData(ibo, indices);
```

GEOMETRY
C/C++ OPENGL

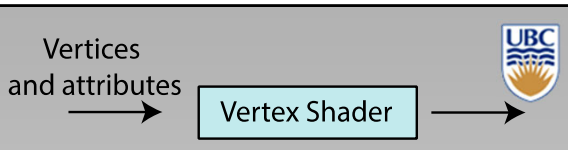


© Alla Sheffer

Opengl RENDERING PIPELINE



Vertex Shader



- Called SEPARATELY for each vertex
- Default: No connectivity info
- **Input:** vertex coordinates in Object Coordinate System
- **Main goal:** set **gl_Position**

Object coordinates -> WORLD coordinates -> VIEW coordinates/Clip Coordinates

FRAGMENT SHADER

- ***Common Tasks:***
  - texture mapping
  - per-pixel lighting and shading
- ***Fragment Shader = Pixel Shader***

Minimal Vertex Shader

```
void main()
{
    // Transforming The Vertex
    vec3 out_pos = projection * transform * vec3(in_pos.xy, 1.0);
    gl_Position = vec4(out_pos.xy, in_pos.z, 1.0);
}
```

Minimal Vertex Shader

```
void main()
{
    // Transforming The Vertex
    vec3 out_pos = projection * transform * vec3(in_pos.xy, 1.0);
    gl_Position = vec4(out_pos.xy, in_pos.z, 1.0);
}
```

Passed from C++

Minimal Vertex Shader

```
void main()
{
    // Transforming The Vertex
    vec3 out_pos = projection * transform * vec3(in_pos.xy, 1.0);
    gl_Position = vec4(out_pos.xy, in_pos.z, 1.0);
}
```

Passed from C++

$$\begin{pmatrix} x \\ y \\ z \\ (w) \end{pmatrix}$$

Minimal Vertex Shader

```
void main()
{
    // Transforming The Vertex
    vec3 out_pos = projection * transform * vec3(in_pos.xy, 1.0);
    gl_Position = vec4(out_pos.xy, in_pos.z, 1.0);
}
```

Passed from C++

$$\begin{pmatrix} x \\ y \\ z \\ (w) \end{pmatrix}$$

View coordinate system

Minimal Fragment Shader

```
out vec4 out_color;
void main()
{
    // Setting Each Pixel To ???
    out_color = vec4(1.0, 0.0, 0.0, 1.0);
}
```

Minimal Fragment Shader

```
out vec4 out_color;
void main()
{
    // Setting Each Pixel To ???
    out_color = vec4(1.0, 0.0, 0.0, 1.0);
}
```

Specify color output

Minimal Fragment Shader

```
out vec4 out_color;
void main()
{
    // Setting Each Pixel To ???
    out_color = vec4(1.0, 0.0, 0.0, 1.0);
}
```

Specify color output

Red, Green, Blue, Alpha

Vertex SHADER – Example 2

```
uniform float uVertexScale;
in vec3 vColor;  // attribute in older GLSL versions
in vec3 position;  // attribute in older GLSL versions
out vec3 fColor; // varying in older GLSL versions

void main()
{
      gl_Position = vec4(position.x * uVertexScale, position.y, 0.0,1.0);
      fColor = vColor;
}
```


Fragment SHADER – Example 2

```
uniform float uVertexScale; // accessible in both shaders
in vec3 fColor;  // out vars from VS must be accompanied by in vars in FS
out vec4 out_color; // must specify fragment shader color output

void main()
{
      out_color = vec4(fColor, 1.0);
}
```

Variable Types

Uniform

- same for all vertices

Out/In (varying)

- computed per vertex, automatically interpolated for fragments

In (attribute)

- values per vertex
- available only in Vertex Shader

Variable Type C++ Examples

Uniform

```
float uVertexScale = 2.0f;
GLint uVertexScaleLoc = glGetUniformLocation(program,
        "uVertexScale");
glUniform1fv(uVertexScaleLoc, 1, uVertexScale);
```

In (attribute)

```
// assuming vbo contains vertex position information already
GLint vpositionLoc = glGetAttribLocation(program, "position");
glEnableVertexAttribArray(vpositionLoc);
glVertexAttribPointer(vpositionLoc, 3, GL_FLOAT, GL_FALSE,
                      sizeof(vec3),(void*)0);
```

CREATING SHADER OBJECTS

```
vertexShader = glCreateShader(GL_VERTEX_SHADER);
glShaderSource(vertexShader, 1, sourceCode, sourceCodeLength);
fragmentShader = glCreateShader(GL_FRAGMENT_SHADER);
glShaderSource(fragmentShader, 1, sourceCode, sourceCodeLength);
```

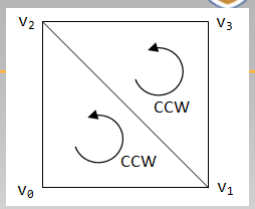
COMPILING

```
glCompileShader(vertexShader); glCompileShader(fragmentShader);
```


LINKING

```
program = glCreateProgram();
glAttachShader(program, vertexShader);
glAttachShader(program, fragmentShader);
glLinkProgram(program);
```

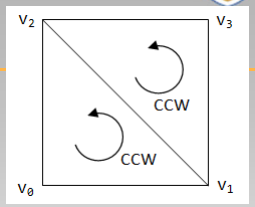
SPRITES: CREATION



Create Quad Vertex Buffer

```
VertexPosTexCoord vertices[] = { v0, v1, v2, v3 };
glGenBuffers(1, &vbo);
glBindBuffer(GL_ARRAY_BUFFER, vbo);
glBufferData(GL_ARRAY_BUFFER, vertices_size, vertices,
GL_STATIC_DRAW);
```


SPRITES: CREATION



Create Quad Index Buffer

```
uint16_t indices[] = { 0, 1, 2, 1, 3, 2 };
glGenBuffers(1, &ibo);
glBindBuffer(GL_ELEMENT_ARRAY_BUFFER,ibo);
glBufferData(GL_ELEMENT_ARRAY_BUFFER, indices_size,
indices, GL_STATIC_DRAW);
```

Load Texture

```
glGenTextures(1, &id);
glBindTexture(GL_TEXTURE_2D, id);
glTexImage2D(GL_TEXTURE_2D, GL_RGBA, width, height, .., data);
```

SPRITES: RENDERING

Bind Buffers

```
glBindVertexArray(vao);
glBindBuffer(GL_ARRAY_BUFFER, vbo);
glBindBuffer(GL_ELEMENT_ARRAY_BUFFER, ibo);
```

Enable Alpha Blending

```
glEnable(GL_BLEND);
glBlendFunc(GL_SRC_ALPHA, GL_ONE_MINUS_SRC_ALPHA);
// Alpha Channel Interpolation
// RGB_o = RGB_src * ALPHA_src + RGB_dst * (1 - ALPHA_src)
```


SPRITES: RENDERING

Bind Texture

```
glActiveTexture(GL_TEXTURE0);
glBindTexture(GL_TEXTURE_2D, turtle_texture.id);
```

Draw

```
glDrawElements(GL_TRIANGLES, 6, ..); // Number of
Indices
```