

WebGL

CS425: Computer Graphics I

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Overview



- Introduction to the graphics rendering pipeline
- WebGL
- Shaders

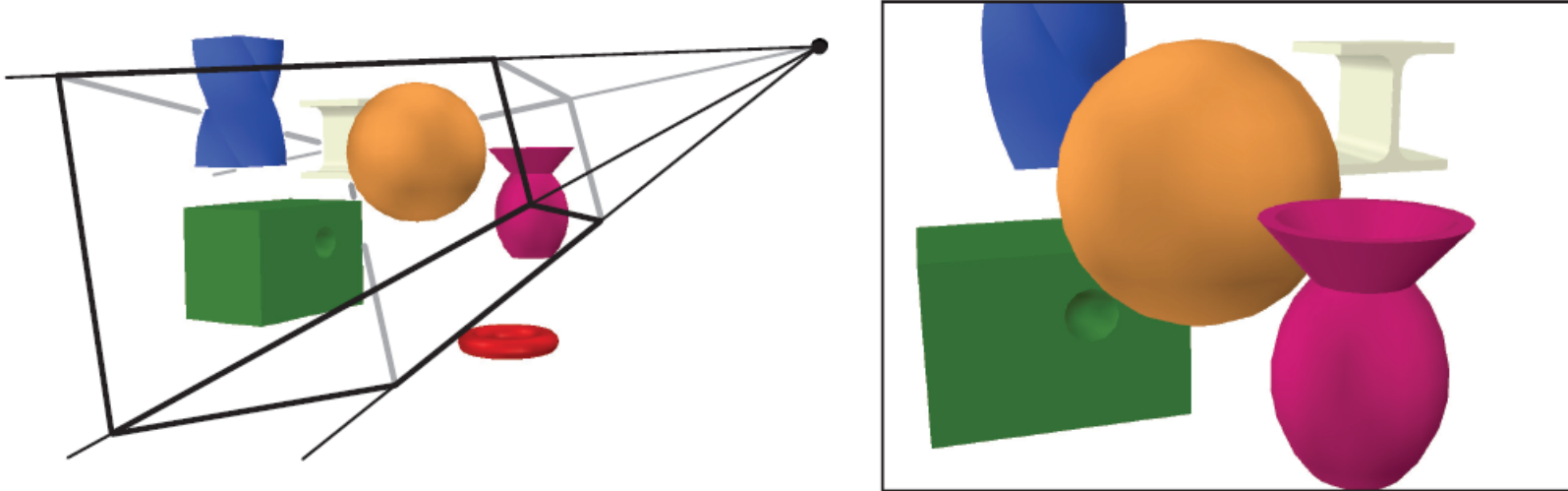
WebGL



- API for rendering graphics within a web browser without plug-ins.
- Hardware accelerated.
- Shader based (no fixed-function API).
 - Fixed function pipeline: set of calls for matrix transformation, lighting.
 - Programmable pipeline: shaders for vertex and fragment processing.
- WebGL 2.0 based on OpenGL ES 3.0.

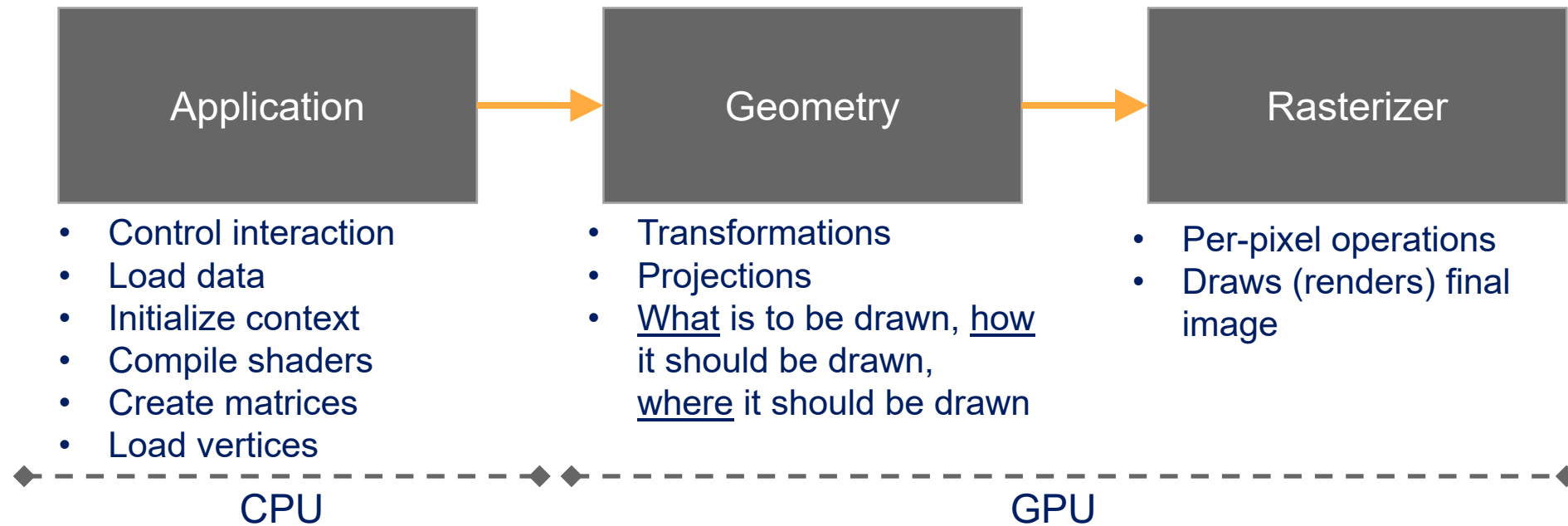
Rendering pipeline

- Graphics system steps to render a scene to a 2D screen.



From: Real-Time Rendering 4th Ed

Rendering pipeline

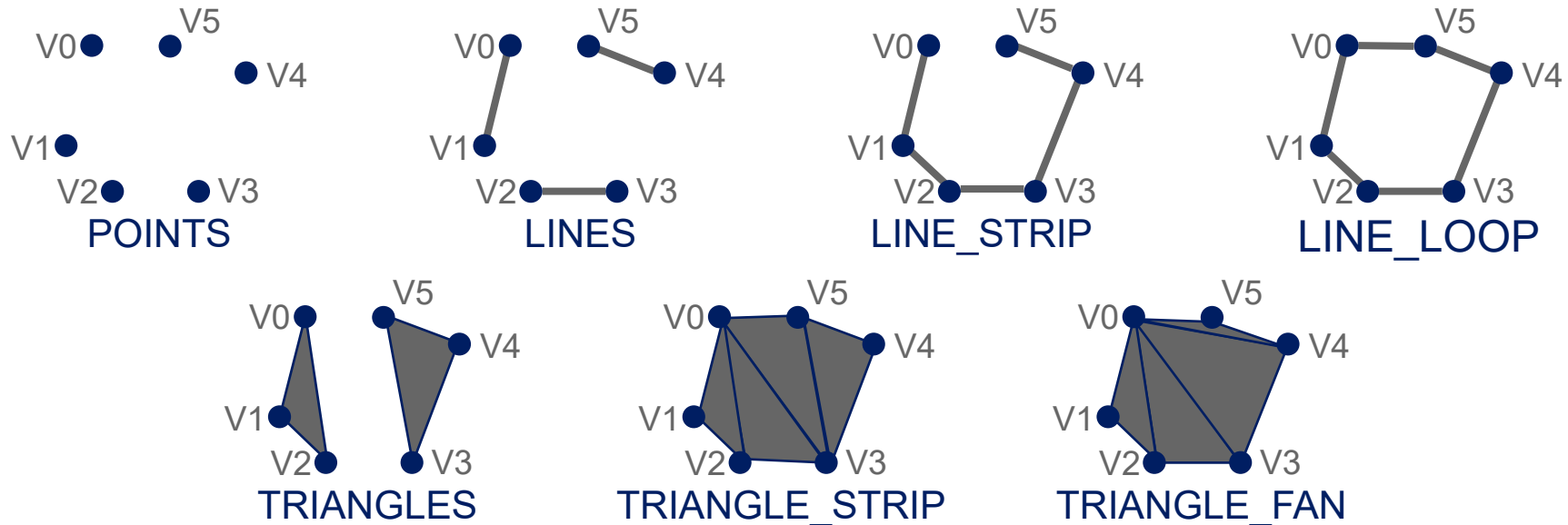


Slowest pipeline stage will determine *rendering speed* (in frames per second).

Simple example: bottleneck stage takes 20 ms to execute. Rendering speed: $1/0.020 = 50$ fps.

Application stage

- Executed on the CPU.
- Sends the geometry to be rendered to the geometry stage.
 - Primitives: points, lines, triangles.



Application stage and WebGL

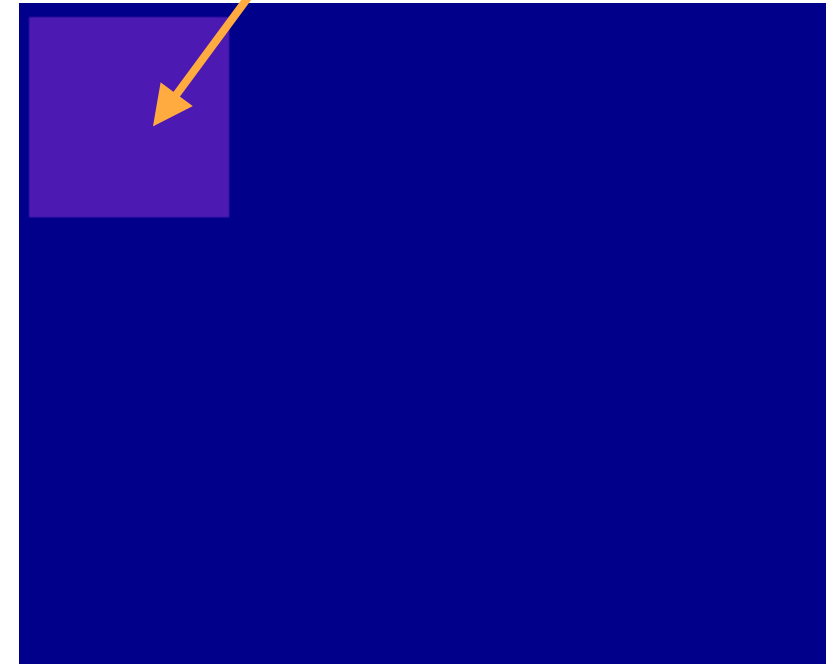
- Important: WebGL is a **state machine**, functions set or retrieve some state in WebGL. Information necessary for rendering is stored in the WebGL context.
- Creates canvas element.
- Loads and initializes shaders (WebGLShader) and programs (WebGLProgram).
- Loads geometries (attributes and buffers).
- Handles rendering loop.

WebGL canvas

```
<html lang="en">
<style>
  body { background-color: darkblue;}
  #glcanvas { width: 100px; height: 100px;}
</style>
<script src="main.js" type="module"></script>
<body>
  <canvas id="glcanvas"></canvas>
</body>
</html>
```

```
function main() {
  var canvas = document.querySelector("#glcanvas");
  gl = canvas.getContext("webgl2");
  gl.clearColor(0.3, 0.1, 0.7, 1.0);
  gl.clear(gl.COLOR_BUFFER_BIT);
}
window.onload = main;
```

WebGL canvas



Loading shaders

- Add GLSL shaders to external files and import them:

```
import vertexShaderSrc from './vertex.glsl.js';  
import fragmentShaderSrc from './fragment.glsl.js'
```

- Simple vertex shader and fragment shaders:

```
export default `#version 300 es  
  
in vec4 position;  
  
void main() {  
    gl_Position = position;  
}  
`;
```

```
export default `#version 300 es  
precision highp float;  
out vec4 outColor;  
  
void main() {  
    outColor = vec4(1, 0, 0, 1);  
}  
`;
```

Loading shaders

- Vertex shader creation:

```
var vertexShader = gl.createShader(gl.VERTEX_SHADER);

gl.shaderSource(vertexShader, vertexShaderSrc);
gl.compileShader(vertexShader);

if (!gl.getShaderParameter(vertexShader, gl.COMPILE_STATUS) ) {
    var info = gl.getShaderInfoLog(vertexShader);
    console.log('Could not compile WebGL program:' + info);
}
```

Loading shaders

- Create a program - combination of two compile WebGL shaders (vertex and fragment):

```
var program = gl.createProgram();

gl.attachShader(program, vertexShader);
gl.attachShader(program, fragmentShader);

gl.linkProgram(program);

if (!gl.getProgramParameter(program, gl.LINK_STATUS) ) {
    var info = gl.getProgramInfoLog(program);
    console.log('Could not compile WebGL program:' + info);
}
```

Sending data to the GPU

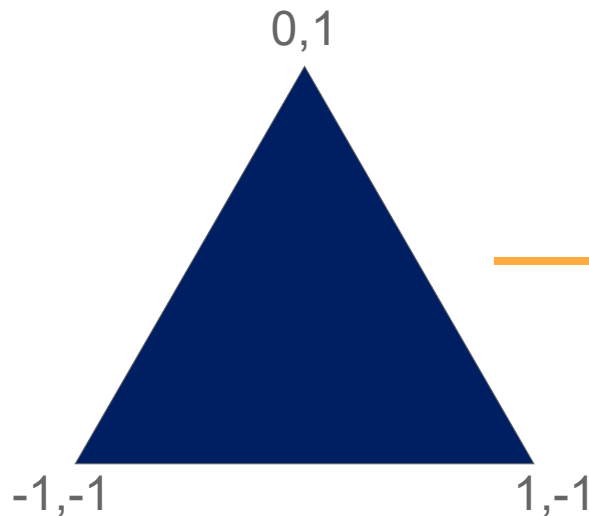


- OpenGL objects are the structures responsible for *transmitting* data to and from the GPU.
- Several types of objects:
 - Buffers: arrays with data to send to the GPU.
 - Vertex positions, normals, indices, texture coordinates, colors.
 - Vertex array object: describes how vertex attributes are stored in the buffers.
 - Many others: uniforms, textures, varyings.

Sending data to the GPU

- Initialization:
 1. Create vertex buffer objects to store vertex data.
 2. Create a vertex array object to specify how this data can be accessed by the vertex shader.
- Every rendering frame:
 1. Use shader programs.
 2. Bind buffers.
 3. Draw arrays.

Buffer



```
var vertices2D = [  
    0.0,  1.0,  
    -1.0, -1.0,  
    1.0, -1.0  
];
```

Creating a buffer to store the triangle:

1. Create buffer object
2. Bind resource to binding point
3. Send strongly typed data to binded buffer

```
var positionBuffer = gl.createBuffer();  
gl.bindBuffer(gl.ARRAY_BUFFER, positionBuffer);  
gl.bufferData(gl.ARRAY_BUFFER, new Float32Array(vertices2D), gl.STATIC_DRAW);
```

Vertex array object

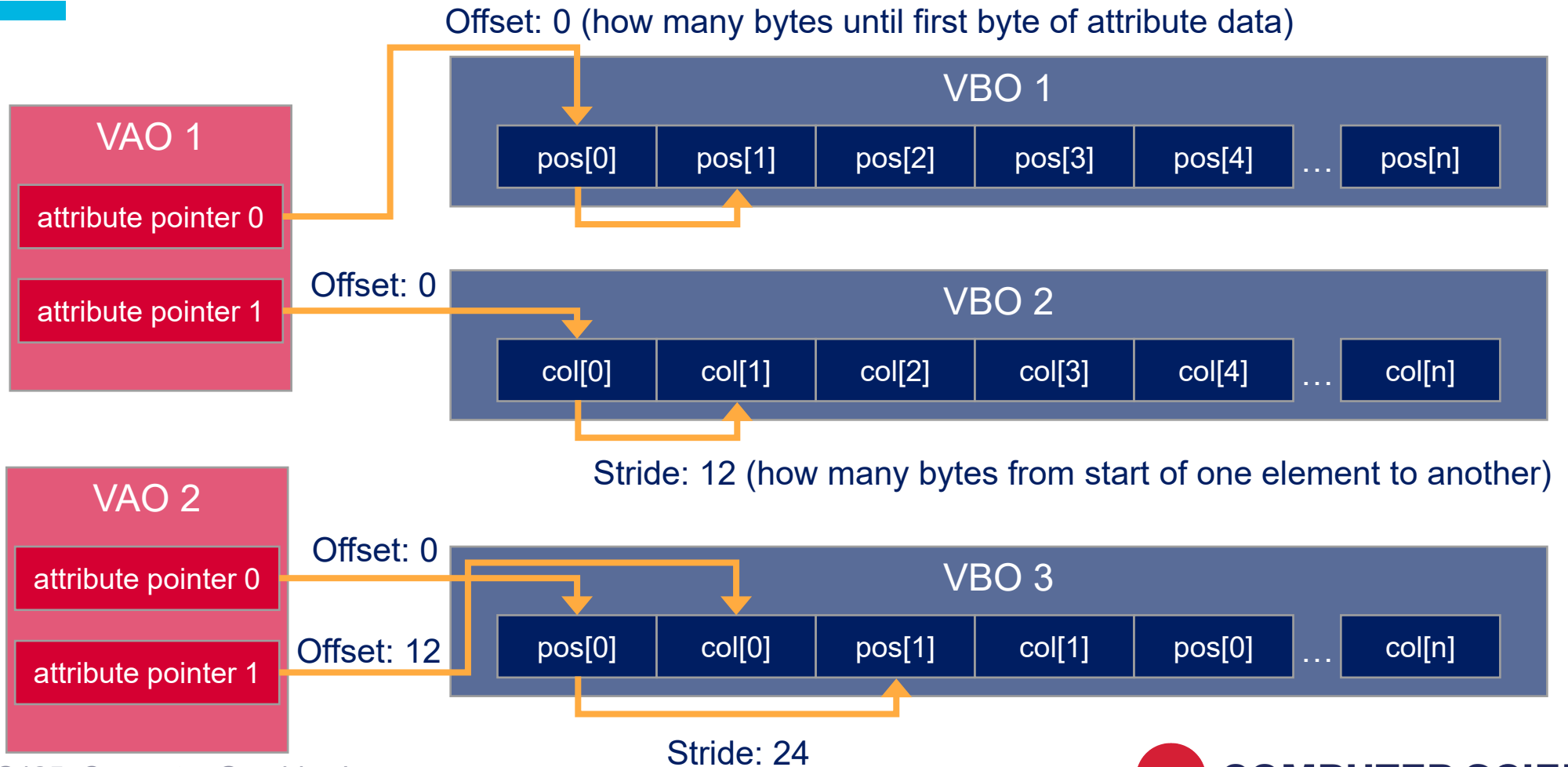
- VAO specifies layout of how data will be accessed by vertex shader.
- Location of the attribute in the program we created:

```
var posAttribLoc = gl.getAttribLocation(program, "position");
```

- Creating a vertex array object so shader can access buffer:

```
var vao = gl.createVertexArray();  
gl.bindVertexArray(vao);  
gl.enableVertexAttribArray(posAttribLoc);  
var size = 2;           // 2 components  
var type = gl.FLOAT;    // 32bit floats  
var normalization = false;  
var stride = 0; var offset = 0;  
gl.bindBuffer(gl.ARRAY_BUFFER, buffer);  
gl.vertexAttribPointer(posAttribLoc, size, type, normalized, stride, offset);
```

Vertex array object



Uniform variables

- Uniforms are variables that can be sent to the shaders from the application.
- Shader:

```
uniform vec4 uColor;
```

- Creating uniform:

```
var uniformLoc = gl.getUniformLocation(program, 'uColor');
```

- Send data to shader (per render call):

```
gl.uniform4v(uniformLoc, new Float32Array([0.0,0.0,1.0,1.0]));
```

Rendering frame

- This will be executed every time we want to render.
- Set viewport (maps clip space to screen space):

```
gl.viewport(0, 0, gl.canvas.width, gl.canvas.height);
```

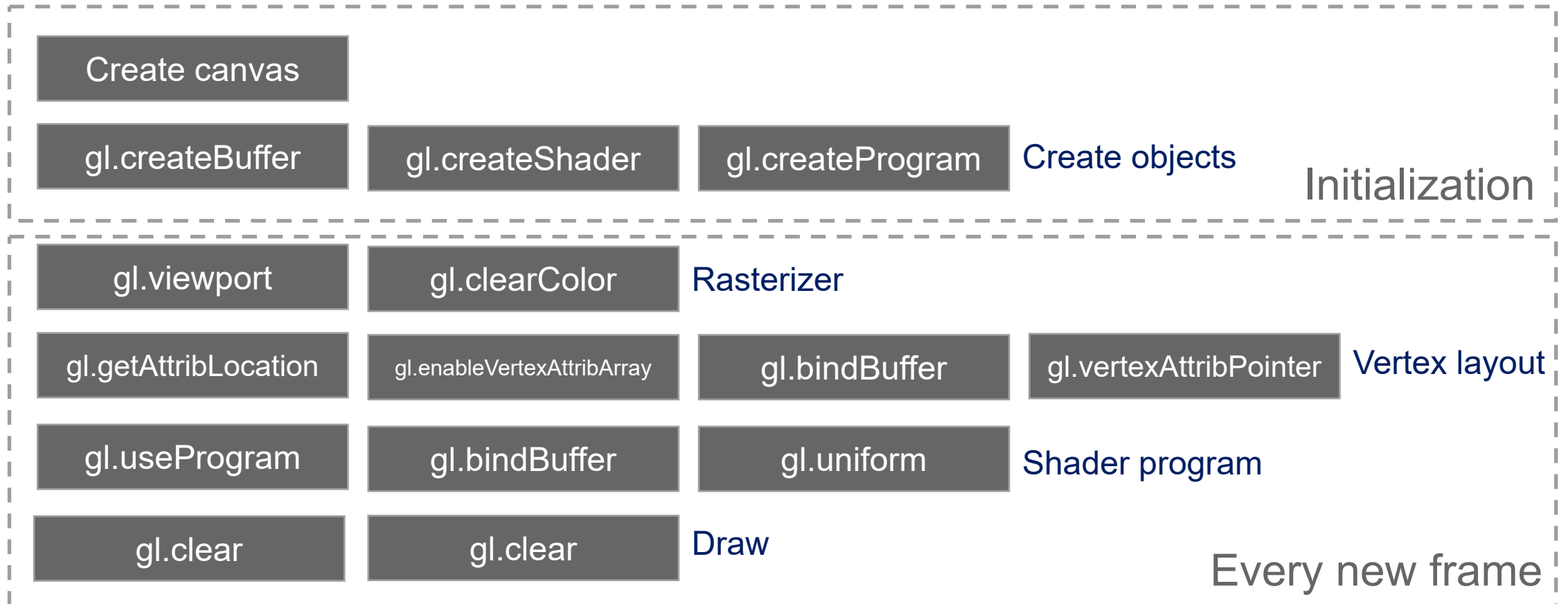
- Clear the canvas:

```
gl.clearColor(0, 0, 0, 0);  
gl.clear(gl.COLOR_BUFFER_BIT);
```

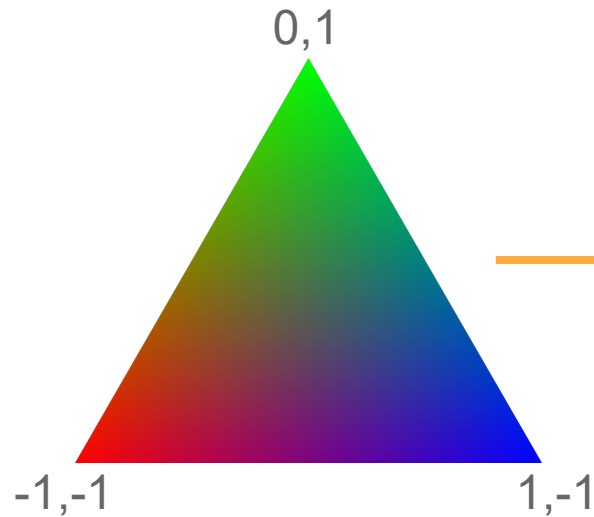
- Use program, bind VAO and draw arrays:

```
gl.useProgram(program);  
gl.bindVertexArray(vao);  
var primitiveType = gl.TRIANGLES;  
var count = 3;  
gl.drawArrays(primitiveType, 0, count);
```

Overview



Simple example



```
var vertices = [  
    0.0, 1.0, 0.0,  
    -1.0, -1.0, 0.0,  
    1.0, -1.0, 0.0  
];
```

```
var colors = [  
    0.0, 1.0, 0.0, 1.0,  
    1.0, 0.0, 0.0, 1.0,  
    0.0, 0.0, 1.0, 1.0,  
];
```

- Initialization:
 1. Create shaders and program.
 2. Create buffers.
 3. Create VAO.
- Rendering:
 1. Use program.
 2. Bind VAO.
 3. Draw arrays.

Simple example: Create shader

```
function createShader(type, source) {  
    var shader = gl.createShader(type);  
  
    gl.shaderSource(shader, source);  
    gl.compileShader(shader);  
  
    if (!gl.getShaderParameter(shader, gl.COMPILE_STATUS) ) {  
        var info = gl.getShaderInfoLog(shader);  
        console.log('Could not compile WebGL program:' + info);  
    }  
  
    return shader;  
}
```

Simple example: Create program

```
function createProgram(vertexShader, fragmentShader) {  
    var program = gl.createProgram();  
  
    gl.attachShader(program, vertexShader);  
    gl.attachShader(program, fragmentShader);  
    gl.linkProgram(program);  
    if (!gl.getProgramParameter(program, gl.LINK_STATUS) ) {  
        var info = gl.getProgramInfoLog(program);  
        console.log('Could not compile WebGL program:' + info);  
    }  
  
    return program;  
}
```

Simple example: Create buffer and VAO

```
function createBuffer(vertices) {  
    var buffer= gl.createBuffer();  
    gl.bindBuffer(gl.ARRAY_BUFFER,buffer);  
    gl.bufferData(gl.ARRAY_BUFFER, new Float32Array(vertices), gl.STATIC_DRAW);  
  
    return buffer;  
}
```

Simple example: Create buffer and VAO

```
function createVAO(posAttribLoc, colorAttribLoc) {
    var vao = gl.createVertexArray();

    gl.bindVertexArray(vao);
    gl.enableVertexAttribArray(posAttribLoc);
    var size = 3;
    var type = gl.FLOAT;
    gl.bindBuffer(gl.ARRAY_BUFFER, posBuffer);
    gl.vertexAttribPointer(posAttribLoc, size, type, false, 0, 0);

    gl.enableVertexAttribArray(colorAttribLoc);
    var size = 4;
    var type = gl.FLOAT;
    gl.bindBuffer(gl.ARRAY_BUFFER, colorBuffer);
    gl.vertexAttribPointer(colorAttribLoc, size, type, false, 0, 0);

    return vao;
}
```


Simple example: shaders

```
export default `#version 300 es

in vec4 position;
in vec4 color;

out vec4 vColor;

void main() {
    vColor = color;
    gl_Position = position;
}
`;
```

```
export default `#version 300 es

precision highp float;

in vec4 vColor;
out vec4 outColor;

void main() {
    outColor = vColor;
}
`;
```

Simple example: Initialization

```
function main() {
  var canvas = document.querySelector("#glcanvas");
  canvas.width = canvas.clientWidth;
  canvas.height = canvas.clientHeight;
  gl = canvas.getContext("webgl2");

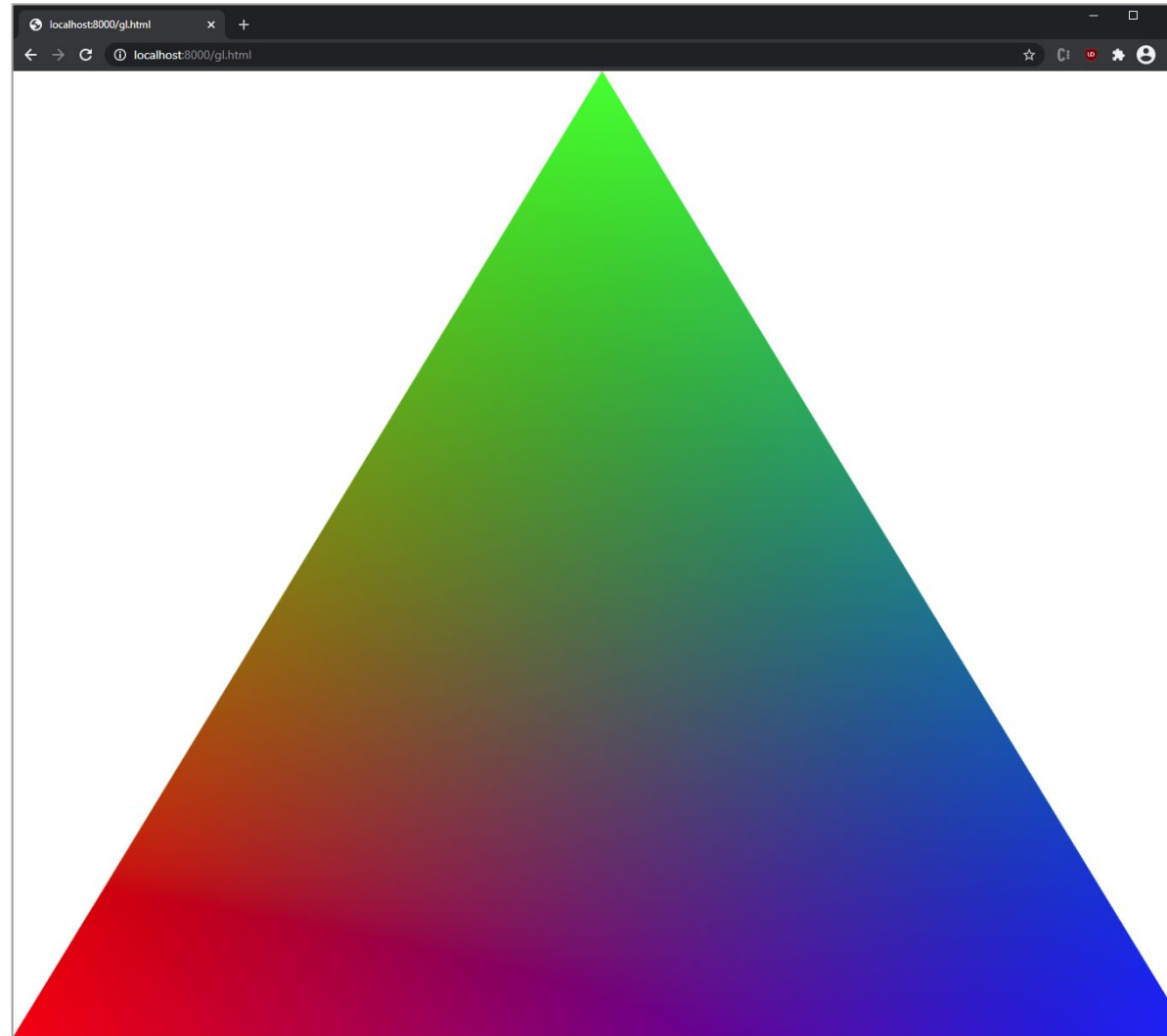
  var vertexShader = createShader(gl.VERTEX_SHADER, vertexShaderSrc);
  var fragmentShader = createShader(gl.FRAGMENT_SHADER, fragmentShaderSrc);
  program = createProgram(vertexShader, fragmentShader);
  posBuffer = createBuffer(vertices);
  colorBuffer = createBuffer(colors);
  var posAttribLoc = gl.getAttribLocation(program, "position");
  var colorAttribLoc = gl.getAttribLocation(program, "color");
  vao = createVAO(posAttribLoc, colorAttribLoc);
}

window.onload = main;
window.requestAnimationFrame(draw);
```

Simple example: Render loop

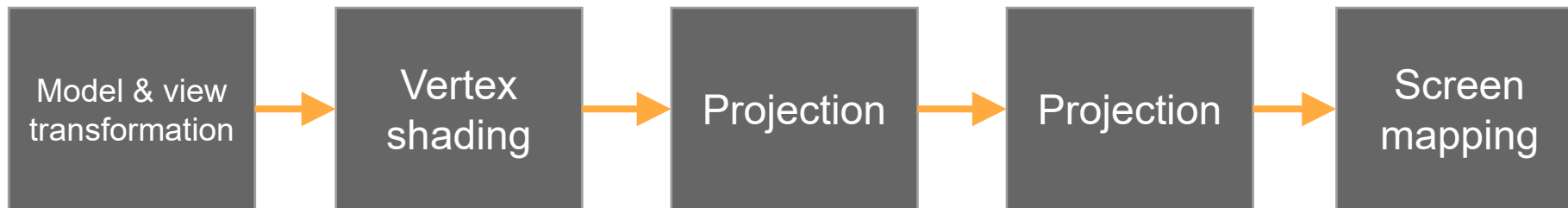
```
function draw() {  
    gl.viewport(0, 0, gl.canvas.width, gl.canvas.height);  
  
    gl.clearColor(1, 1, 1, 1);  
    gl.clear(gl.COLOR_BUFFER_BIT);  
  
    gl.useProgram(program);  
    gl.bindVertexArray(vao);  
    var primitiveType = gl.TRIANGLES;  
    var count = 3;  
    gl.drawArrays(primitiveType, 0, count);  
  
}
```

Simple example



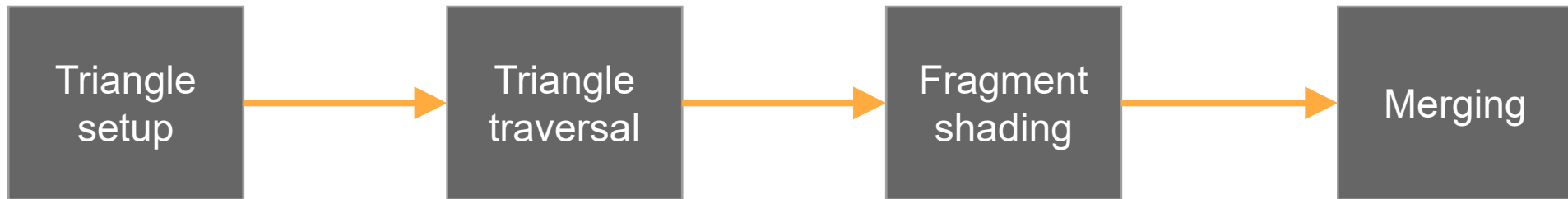
Geometry stage

- Responsible for most of the per-polygon and per-vertex operations.



Rasterizer stage

- Responsible for the computation of fragment and pixel colors.



Lab

- Create a web application to render triangles. This application should be composed of two main elements: a configuration panel, and a WebGL canvas.
- The configuration panel should be composed of:
 1. Three sliders to set the current RGB color of triangles.
 2. One slider with the number of triangles to be rendered in the WebGL canvas (minimum of 1 triangle, maximum of 100 triangles). Position and size of triangles should be randomly selected, making sure that *all* triangles are rendered inside canvas.
 3. Start and stop buttons. Once start is pressed, current RGB color should randomly change, *smoothly* updating the RGB sliders and color of rendered triangles.
- WebGL canvas should render triangles according to configuration panel.

Useful links



https://developer.mozilla.org/en-US/docs/Web/API/WebGL_API

<https://www.khronos.org/registry/webgl/specs/latest/2.0/>

<https://www.khronos.org/files/webgl20-reference-guide.pdf>