

CSE160 – Lecture 2

- Linear Algebra Review
- Survey
- About GL WebGL
- GLSL Shader Overview
- Assignment 0 and 1
- Administrative
- Q&A

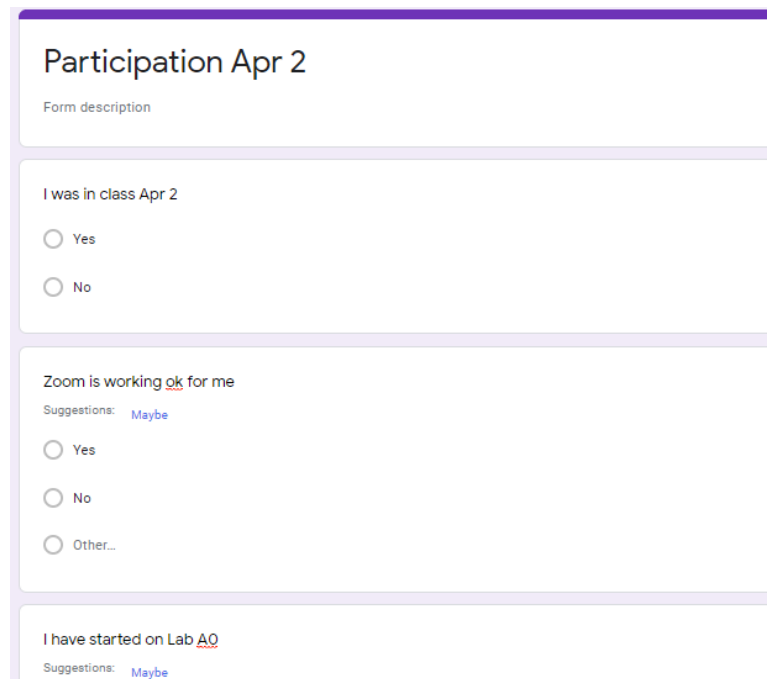
Linear Algebra Review

(On document camera)

- Triangle made of vertices which are Points
- Vectors ($P1-P2$)
- $P1+V=P2$
- Vector magnitude (normalizing vectors),
what does $||xx||$ mean?
- Dot product of two vectors (Wikipedia)
- Cross product of two vectors
- Matrix
- Matrix * Point
- Matrix * Matrix

Break time – 4 minutes

(Survey link in Zoom Chat)



The image shows a screenshot of a Google Forms survey. The title is "Participation Apr 2". Below the title is a section for "Form description". The first question is "I was in class Apr 2" with two radio button options: "Yes" and "No". The second question is "Zoom is working ok for me" with a "Suggestions:" label and a blue link "Maybe". It has three radio button options: "Yes", "No", and "Other...". The third question is "I have started on Lab A0" with a "Suggestions:" label and a blue link "Maybe".

Participation Apr 2

Form description

I was in class Apr 2

☐ Yes

☐ No

Zoom is working ok for me

Suggestions: [Maybe](#)

☐ Yes

☐ No

☐ Other...

I have started on Lab A0

Suggestions: [Maybe](#)

About GL and WebGL

OpenGL version history

Version	Release Date	Features
1.1	March 4, 1997	Texture objects
1.2	March 16, 1998	3D textures, BGRA and packed pixel formats, ^[23] introduction of the <i>imaging subset</i> useful to image-processing applications
1.2.1	October 14, 1998	A concept of ARB extensions
1.3	August 14, 2001	Multitexturing , multisampling, texture compression
1.4	July 24, 2002	Depth textures, GLSLang ^[24]
1.5	July 29, 2003	Vertex Buffer Object (VBO), Occlusion Queries ^[25]
2.0	September 7, 2004	GLSL 1.1, MRT , Non Power of Two textures, Point Sprites, ^[26] Two-sided stencil ^[25]
2.1	July 2, 2006	GLSL 1.2, Pixel Buffer Object (PBO), sRGB Textures ^[25]
3.0	August 11, 2008	GLSL 1.3, Texture Arrays, Conditional rendering, Frame Buffer Object (FBO) ^[27]
3.1	March 24, 2009	GLSL 1.4, Instancing, Texture Buffer Object, Uniform Buffer Object, Primitive restart ^[28]
3.2	August 3, 2009	GLSL 1.5, Geometry Shader, Multi-sampled textures ^[29]
3.3	March 11, 2010	GLSL 3.30, Backports as much function as possible from the OpenGL 4.0 specification
4.0	March 11, 2010	GLSL 4.00, Tessellation on GPU, shaders with 64-bit precision ^[30]
4.1	July 26, 2010	GLSL 4.10, Developer-friendly debug outputs, compatibility with OpenGL ES 2.0 ^[31]
4.2	August 8, 2011 ^[32]	GLSL 4.20, Shaders with atomic counters, draw transform feedback instanced, shader packing, performance improvements
4.3	August 6, 2012 ^[33]	GLSL 4.30, Compute shaders leveraging GPU parallelism, shader storage buffer objects, high-quality ETC2/EAC texture compression, increased memory security, a multi-application robustness extension, compatibility with OpenGL ES 3.0 ^[34]
4.4	July 22, 2013 ^[35]	GLSL 4.40, Buffer Placement Control, Efficient Asynchronous Queries, Shader Variable Layout, Efficient Multiple Object Binding, Streamlined Porting of Direct3D applications, Bindless Texture Extension, Sparse Texture Extension ^[35]
4.5	August 11, 2014 ^{[8][36]}	GLSL 4.50, Direct State Access (DSA), Flush Control, Robustness, OpenGL ES 3.1 API and shader compatibility, DX11 emulation features
4.6	July 31, 2017 ^{[37][38]}	GLSL 4.60, More efficient geometry processing and shader execution, more information, no error context, polygon offset clamp, SPIR-V, anisotropic filtering



Example (old style)

type of object

location of vertex

```
glBegin(GL_POLYGON)
  glVertex3f(0.0, 0.0, 0.0);
  glVertex3f(0.0, 1.0, 0.0);
  glVertex3f(0.0, 0.0, 1.0);
glEnd();
```

end of object definition



Example (GPU based)

- Put geometric data in an array

```
var points = [  
    vec3(0.0, 0.0, 0.0) ,  
    vec3(0.0, 1.0, 0.0) ,  
    vec3(0.0, 0.0, 1.0) ,  
];
```

- Send array to GPU
- Tell GPU to render as triangle



OpenGL 3.1

- Totally shader-based
 - No default shaders
 - Each application must provide both a vertex and a fragment shader
- No immediate mode
- Few state variables
- Most 2.5 functions deprecated
- Backward compatibility not required
 - Exists a compatibility extension



Other Versions

- OpenGL ES
 - Embedded systems
 - Version 1.0 simplified OpenGL 2.1
 - Version 2.0 simplified OpenGL 3.1
 - Shader based
- WebGL
 - Javascript implementation of ES 2.0
 - Supported on newer browsers
- OpenGL 4.1, 4.2,
 - Add geometry, tessellation, compute shaders



Lack of Object Orientation

- All versions of OpenGL are not object oriented so that there are multiple functions for a given logical function
- Example: sending values to shaders
 - `gl.uniform3f`
 - `gl.uniform2i`
 - `gl.uniform3dv`
- Underlying storage mode is the same



The University of New Mexico

WebGL function format

function name

dimension

`gl.uniform3f(x, y, z)`

belongs to WebGL canvas

`x, y, z` are variables

`gl.uniform3fv(p)`

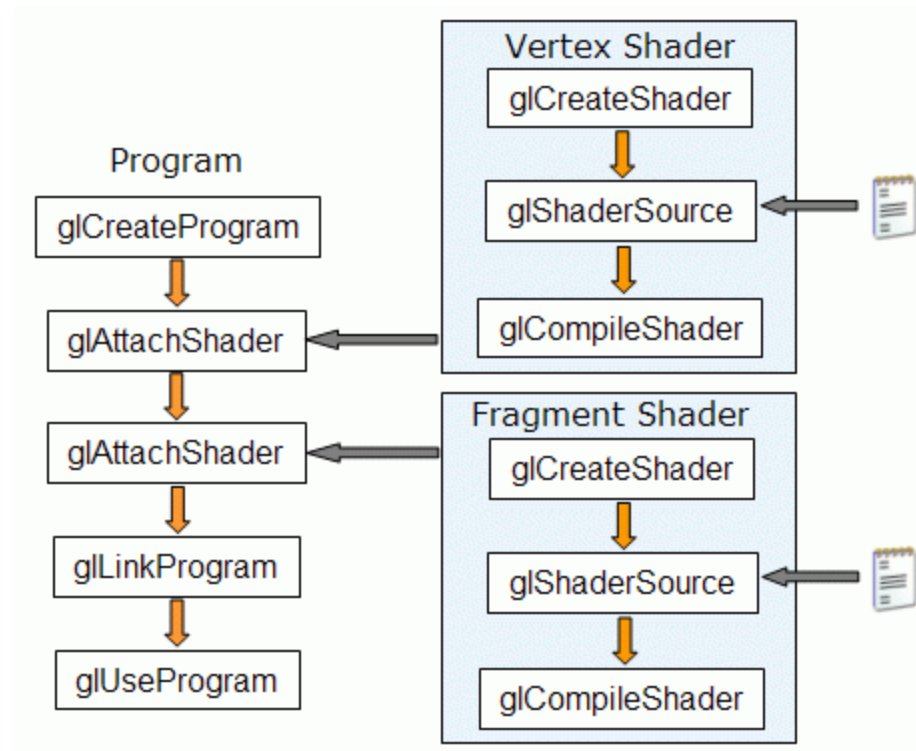
`p` is an array



WebGL constants

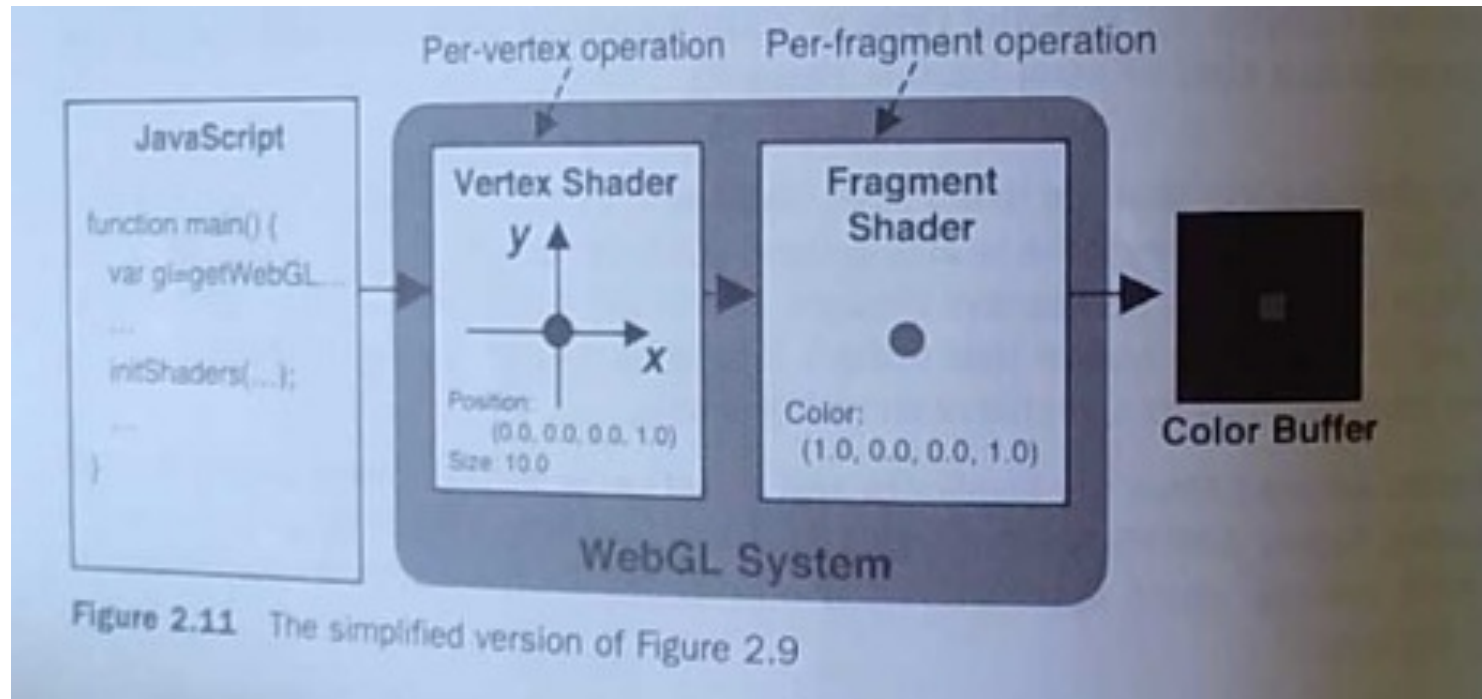
- Most constants are defined in the canvas object
 - In desktop OpenGL, they were in #include files such as `gl.h`
- Examples
 - desktop OpenGL
 - `glEnable(GL_DEPTH_TEST);`
 - WebGL
 - `gl.enable(gl.DEPTH_TEST)`
 - `gl.clear(gl.COLOR_BUFFER_BIT)`

GLSL Shaders Overview



CPU

GPU



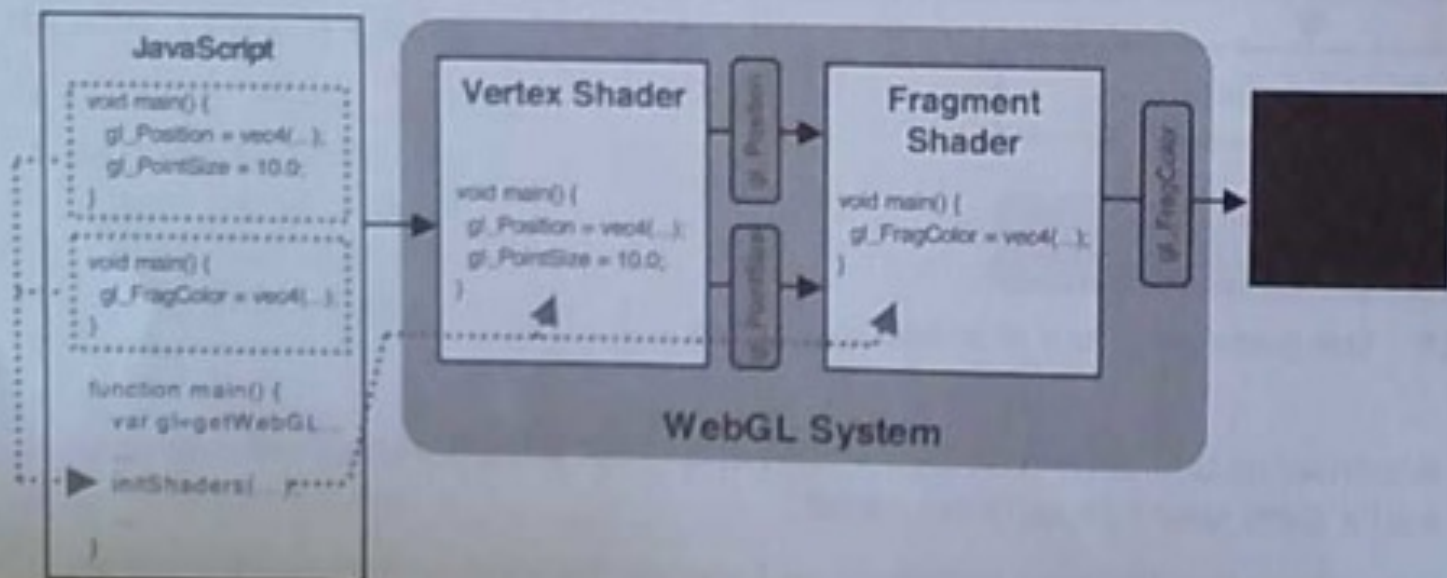
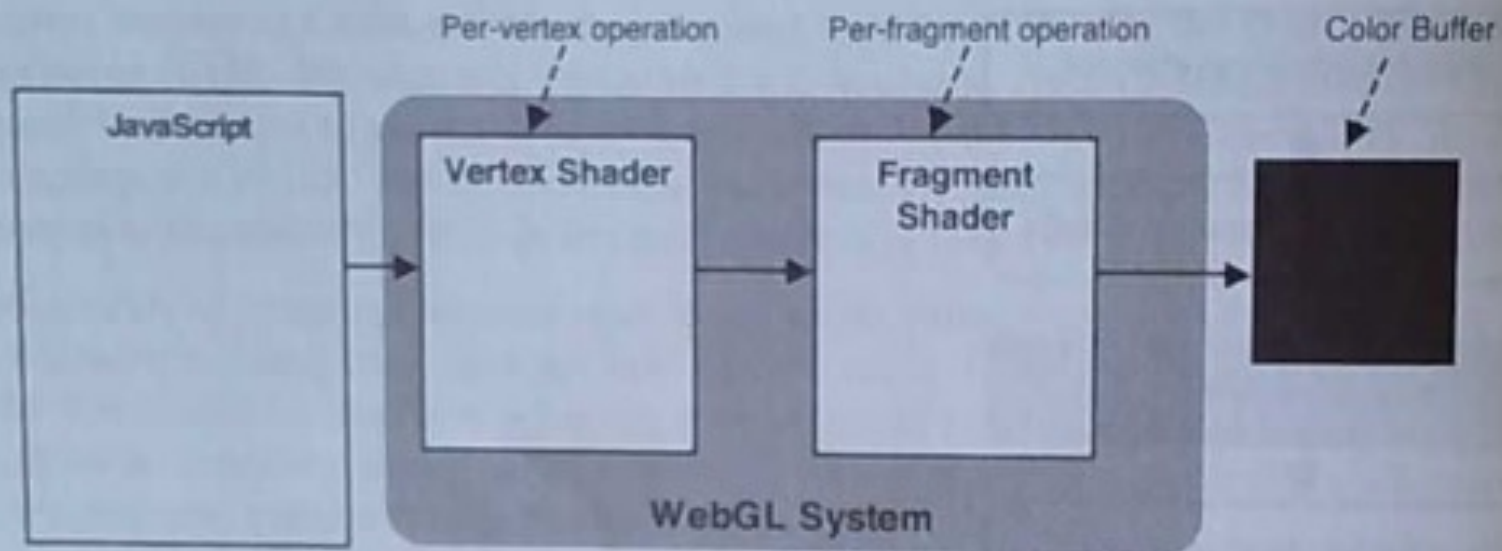


Figure 2.14 Behavior of `initShaders()`



Example (old style)

type of object

location of vertex

```
glBegin(GL_POLYGON)
  glVertex3f(0.0, 0.0, 0.0);
  glVertex3f(0.0, 1.0, 0.0);
  glVertex3f(0.0, 0.0, 1.0);
glEnd();
```

end of object definition



Example (GPU based)

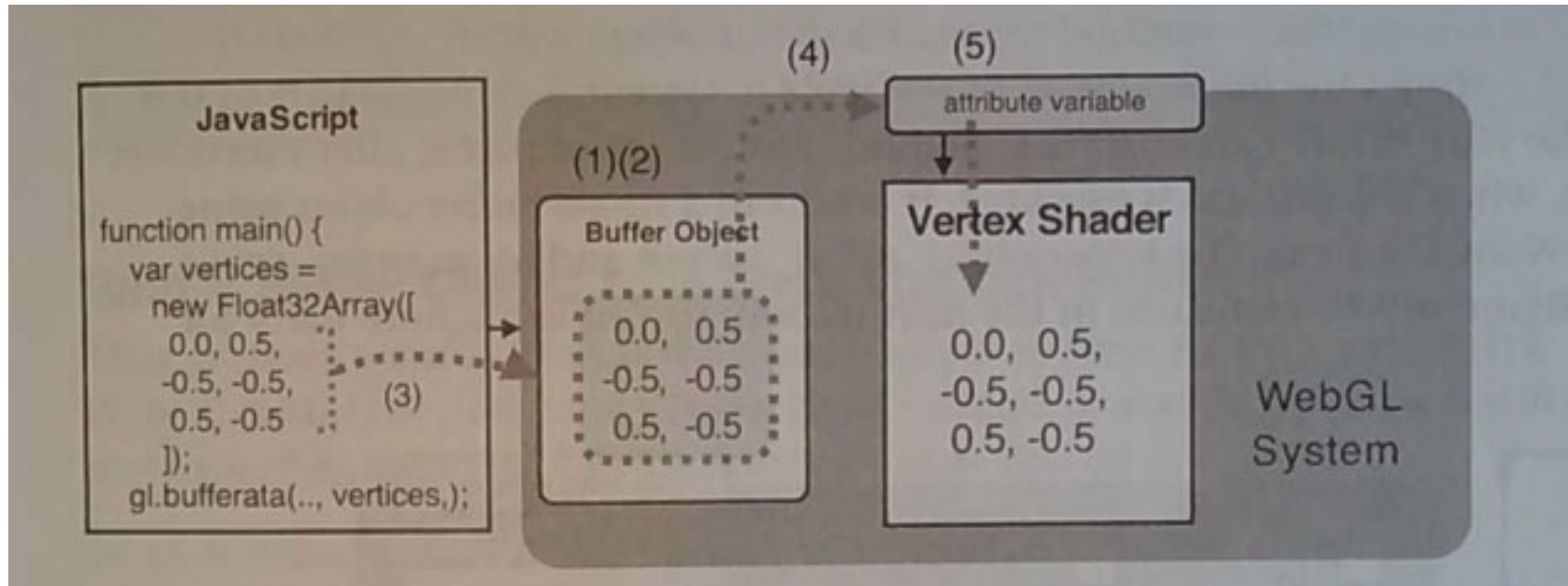
- Put geometric data in an array

```
var points = [  
    vec3(0.0, 0.0, 0.0) ,  
    vec3(0.0, 1.0, 0.0) ,  
    vec3(0.0, 0.0, 1.0) ,  
];
```

- Send array to GPU
- Tell GPU to render as triangle

CPU

GPU



```

51 var vertices = new Float32Array([
52     0.0, 0.5,   -0.5, -0.5,   0.5, -0.5
53 ]);
54 var n = 3; // The number of vertices
55
56 // Create a buffer object
57 var vertexBuffer = gl.createBuffer();
58 if (!vertexBuffer) {
59     console.log('Failed to create the buffer object ');
60     return -1;
61 }
62
63 // Bind the buffer object to target
64 gl.bindBuffer(gl.ARRAY_BUFFER, vertexBuffer);
65 // Write data into the buffer object
66 gl.bufferData(gl.ARRAY_BUFFER, vertices, gl.STATIC_DRAW);
67
68 var a_Position = gl.getAttribLocation(gl.program, 'a_Position');
69 ...
71 // Assign the buffer object to a_Position variable
72 gl.vertexAttribPointer(a_Position, 2, gl.FLOAT, false, 0, 0);

```

```

75
76 // Enable the assignment to a_Position variable
77 gl.enableVertexAttribArray(a_Position);
78
79 return n;
80 }

```

The new function `initVertexBuffers()` is defined at line 50 and used at line 34 to set up the vertex buffer object. The function stores multiple vertices in the buffer object and then completes the preparations for passing it to a vertex shader:

```

33 // Set the positions of vertices
34 var n = initVertexBuffers(gl);

```

The return value of this function is the number of vertices being drawn, stored in the variable `n`. Note that in case of error, `n` is negative.

As in the previous examples, the drawing operation is carried out using a single call to `gl.drawArrays()` at Line 48. This is similar to `ClickedPoints.js` except that `n` is passed as the third argument of `gl.drawArrays()` rather than the value 1:

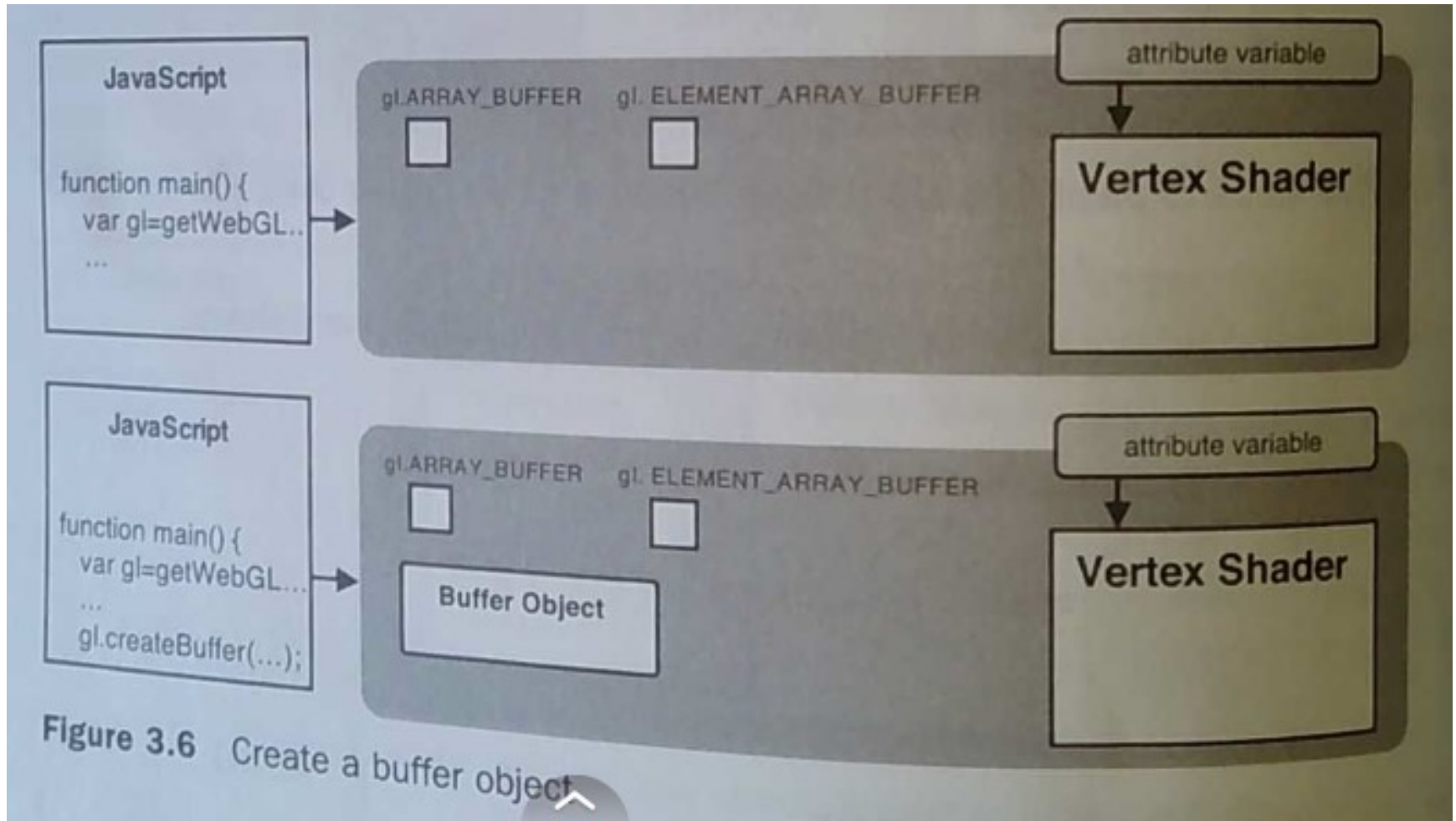
```

46 // Draw three points
47 gl.drawArrays(gl.POINTS, 0, n); // n is 3

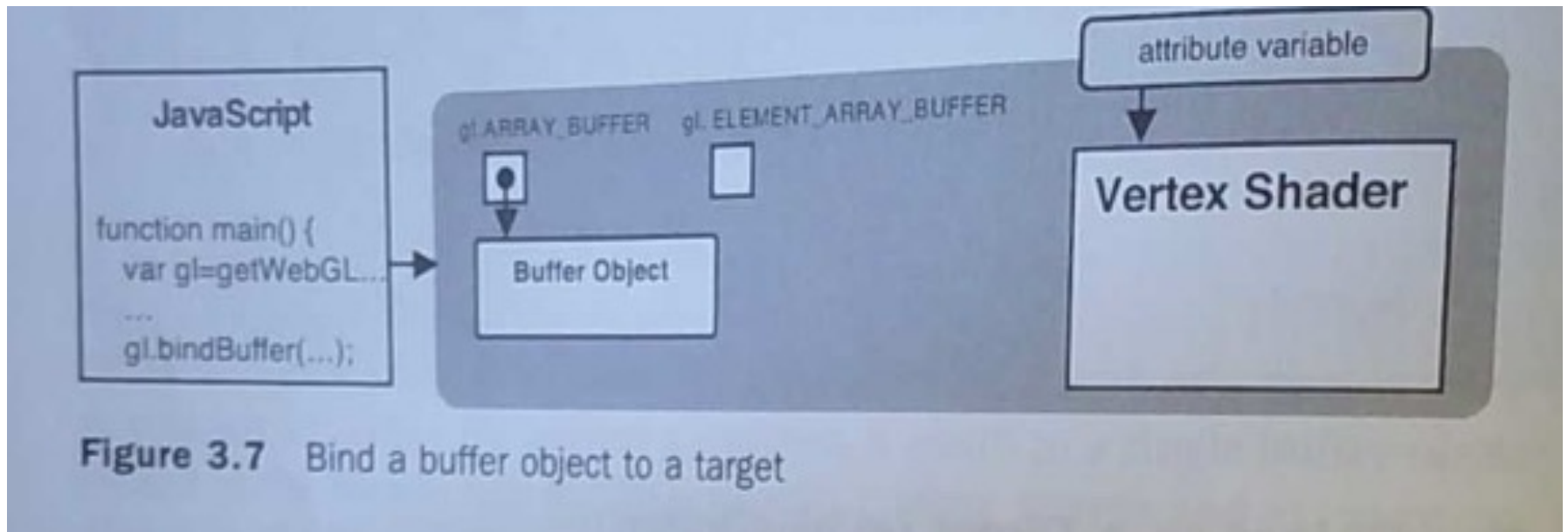
```

Because you are using a buffer object to pass multiple vertices to a vertex shader in `initVertexBuffers()`, you need to specify the number of vertices in the object as the third parameter of `gl.drawArrays()` so that WebGL then knows to draw a shape using all the vertices in the buffer object.

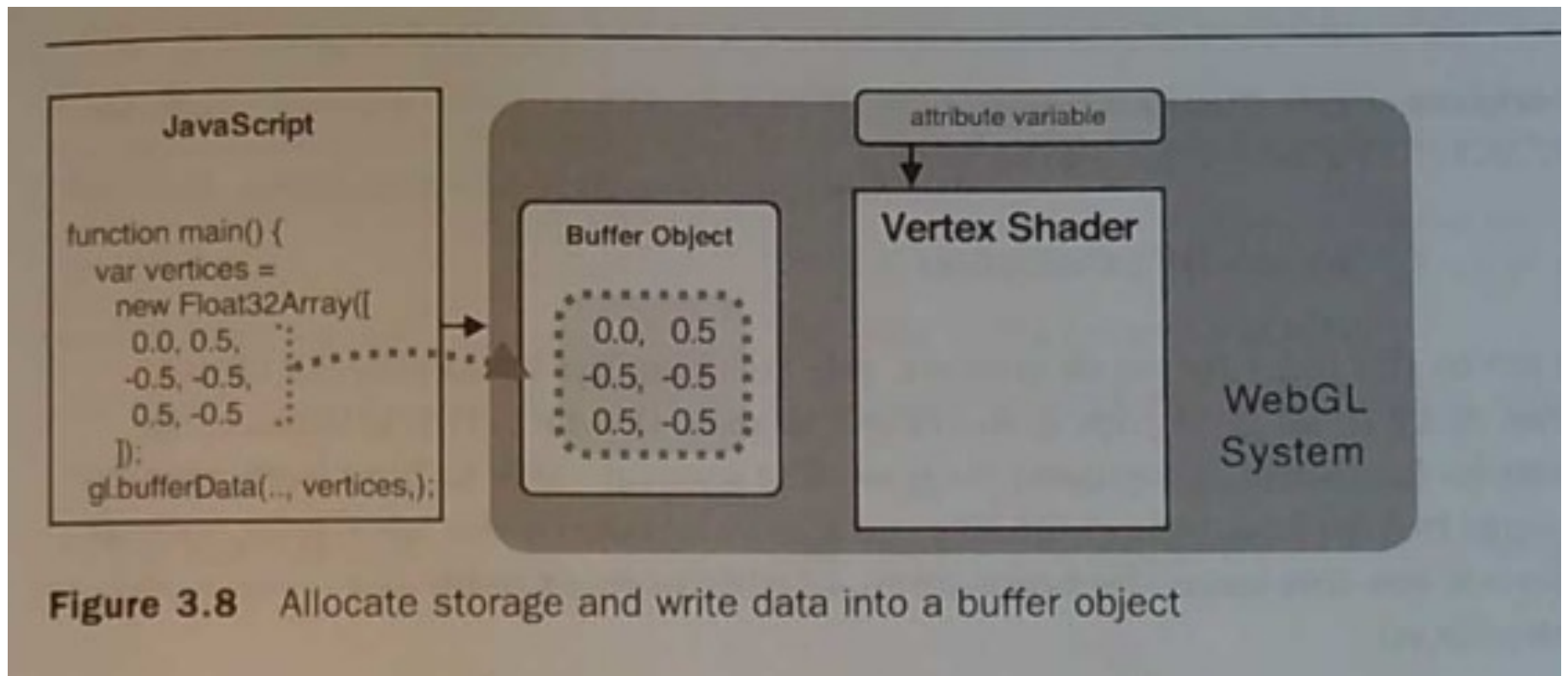
gl.createBuffer()



gl.bindBuffer()



gl.bufferData()



gl.vertexAttribPointer()

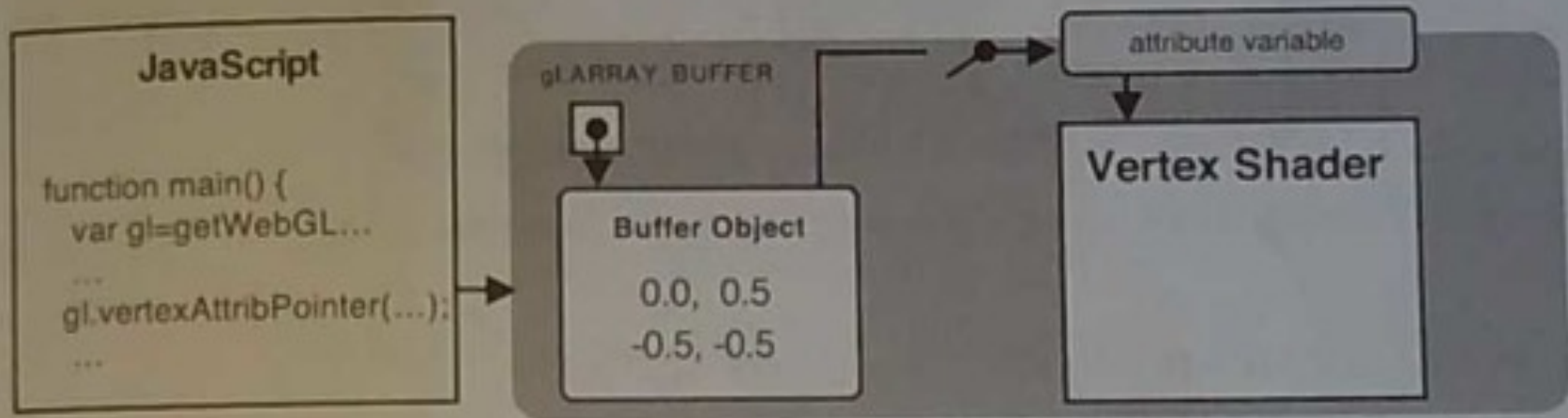


Figure 3.9 Assign a buffer object to an attribute variable

gl.vertexAttribPointer()

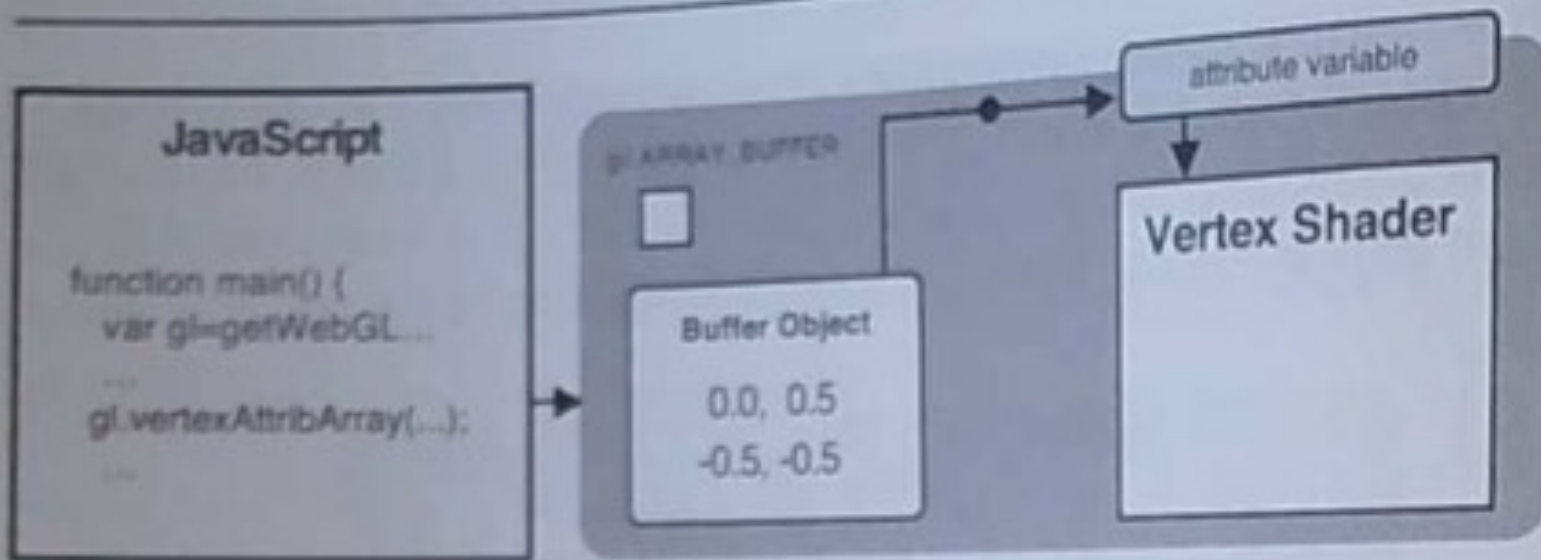
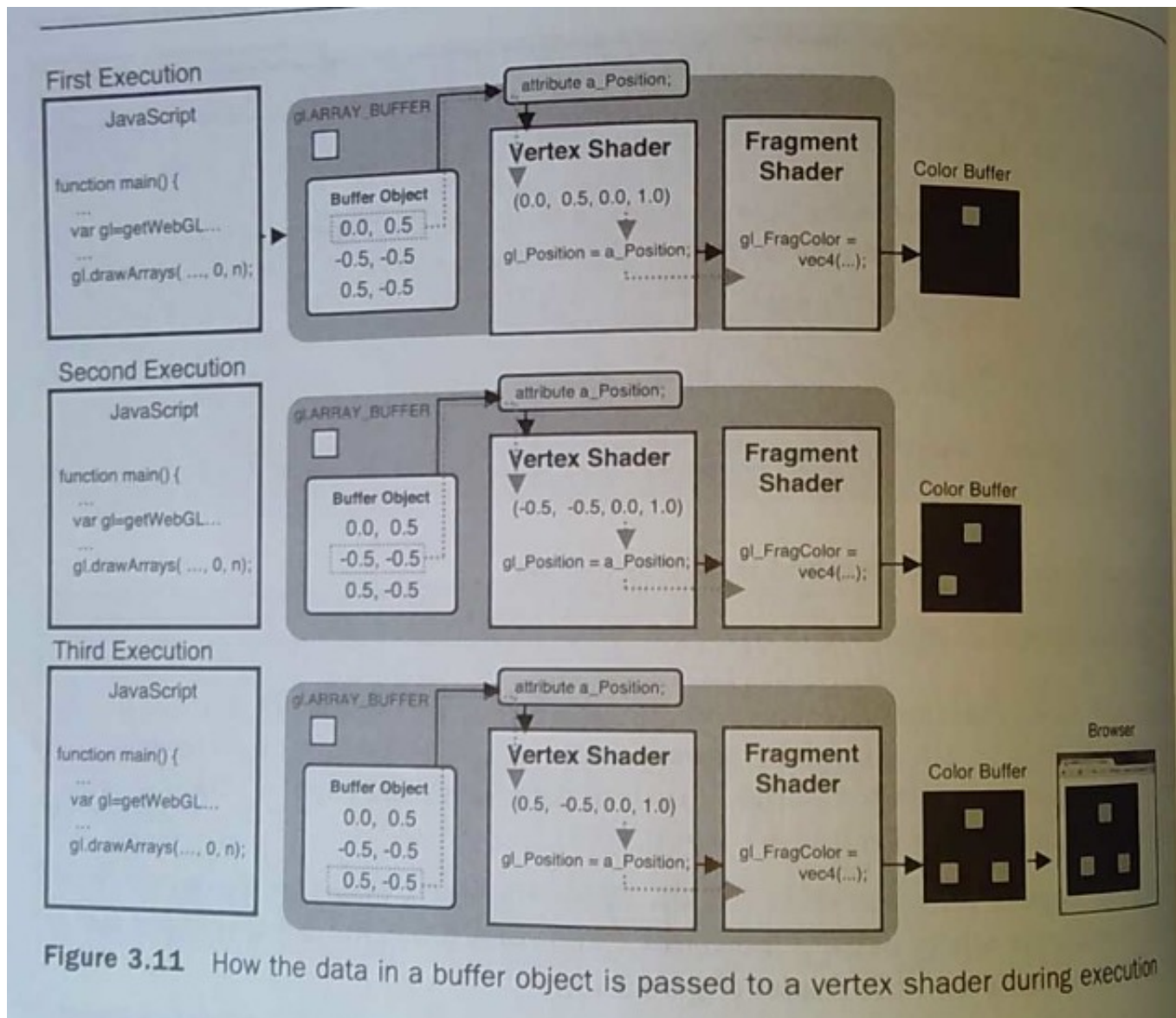


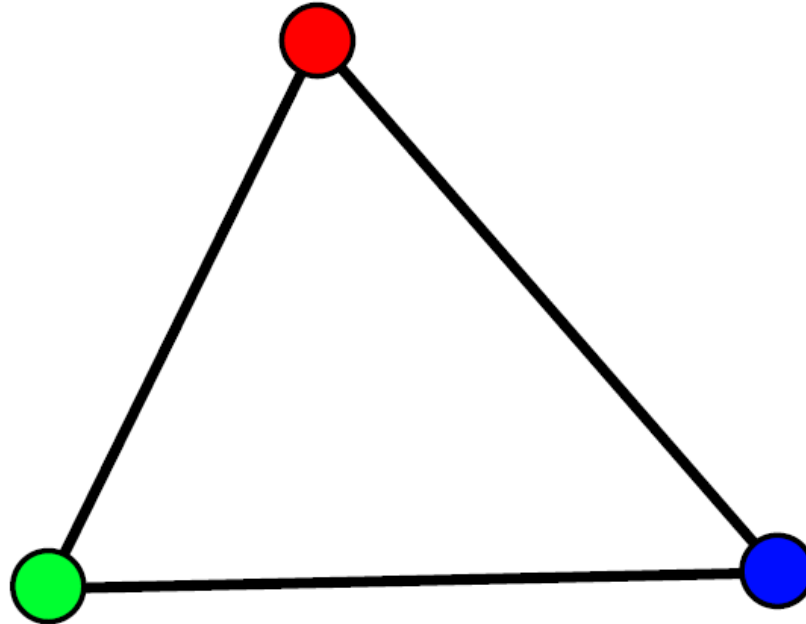
Figure 3.10 Enable the assignment of a buffer object to an attribute variable

Vertex shader runs for *each* item in the buffer



How is shading done in OpenGL?

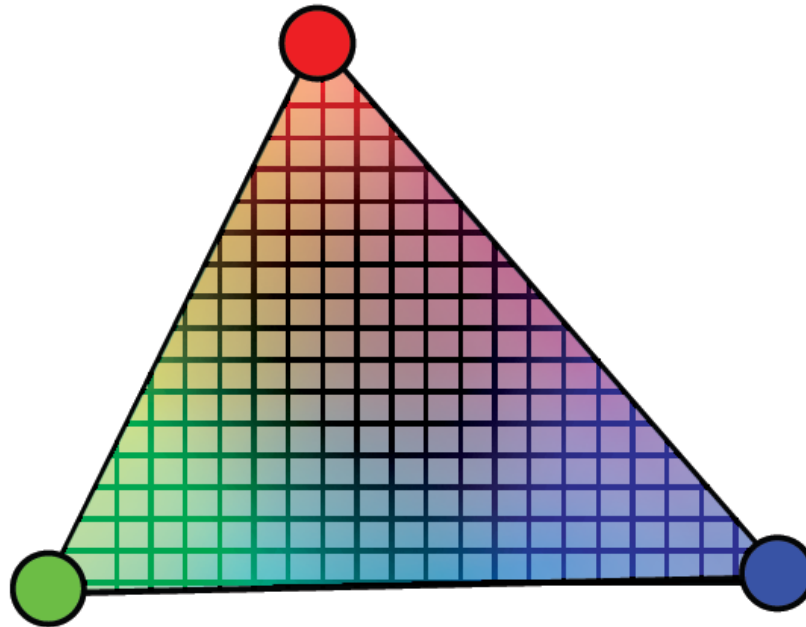
1. Attributes are specified on vertices.



How is shading done in OpenGL?

2. Attributes are interpolated across triangles by the rasterizer

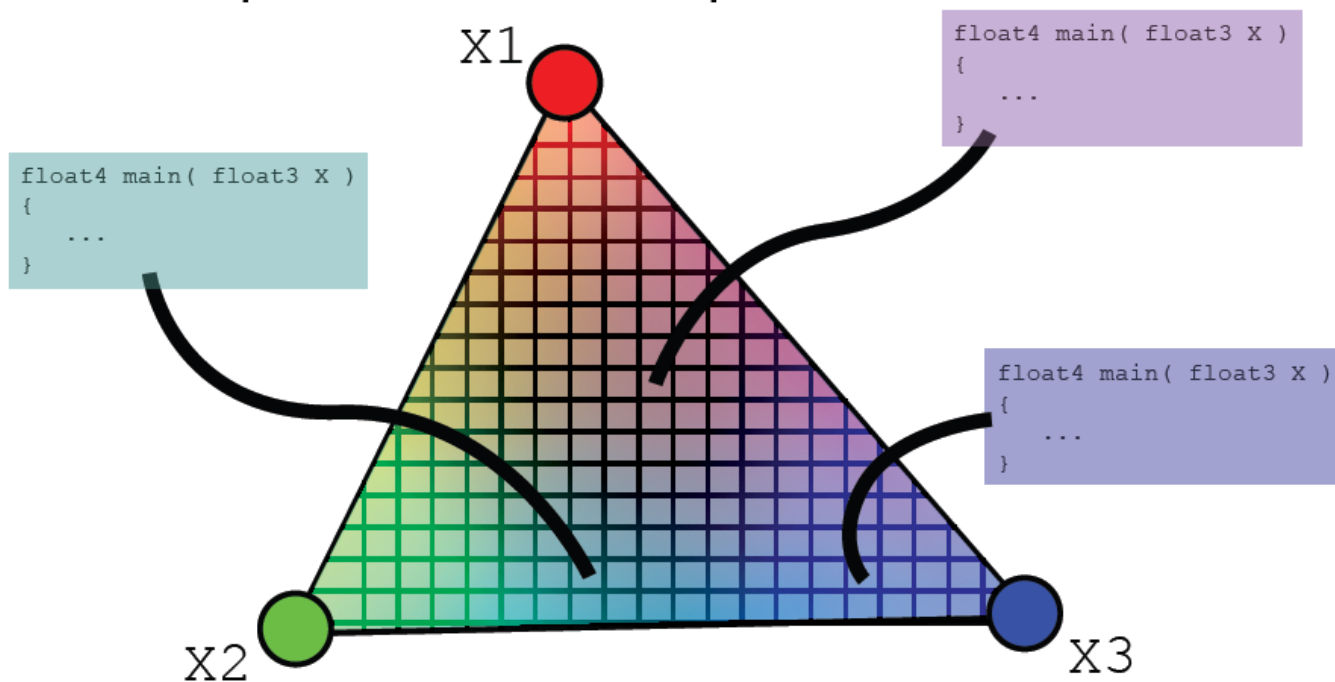
(see appendix for details)



Rasterizer also breaks the triangle into “fragments.”

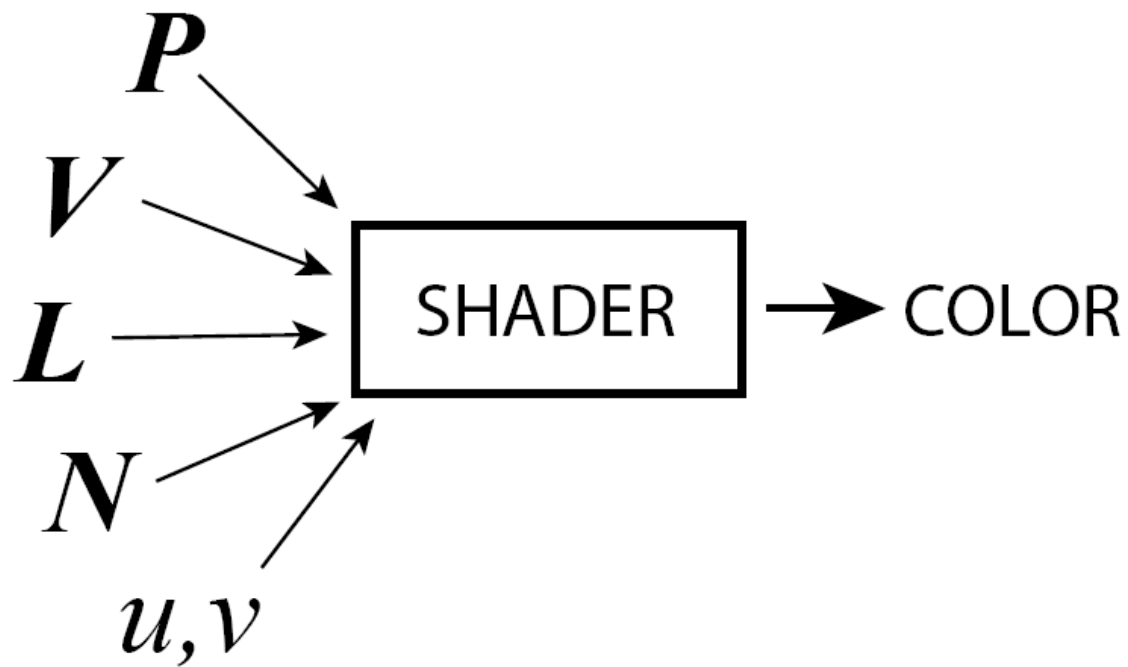
How is shading done in OpenGL?

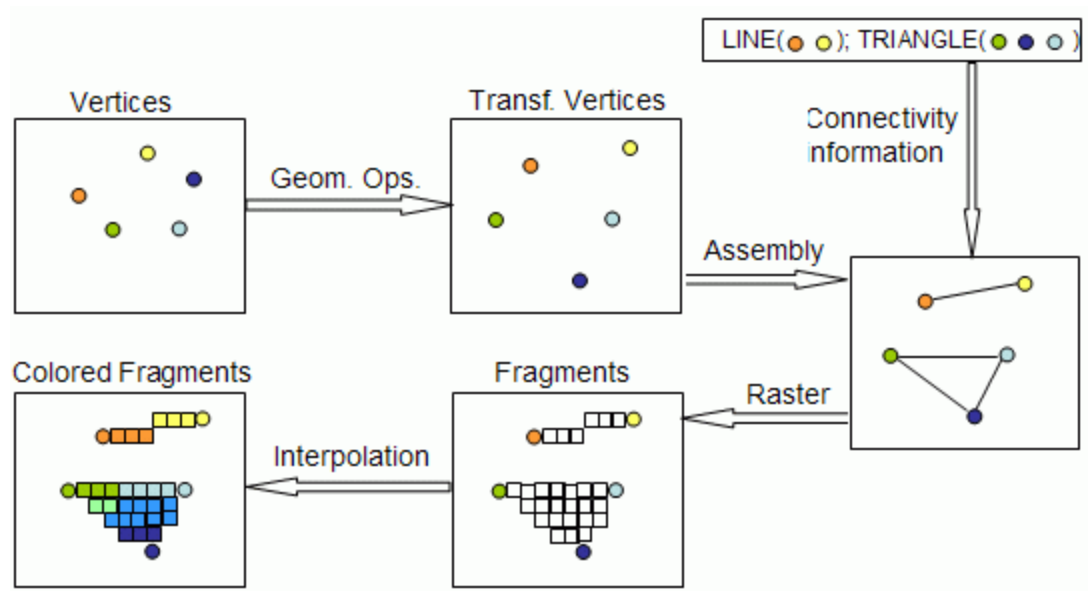
3. Each fragment runs the shader using interpolated values as inputs.



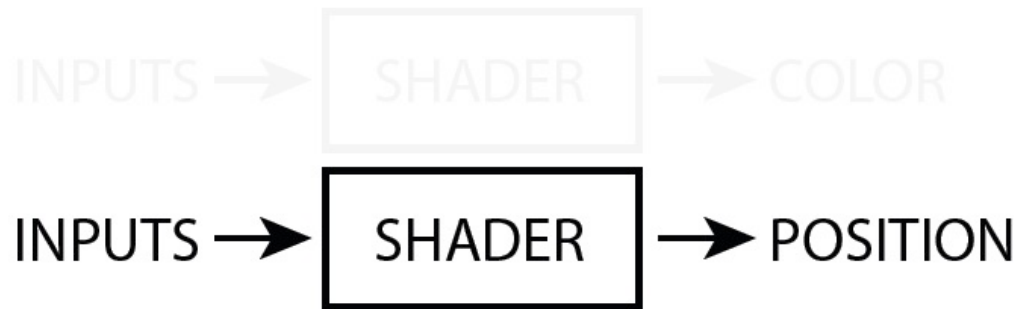
Exact same routine, different inputs.

What is a shader?

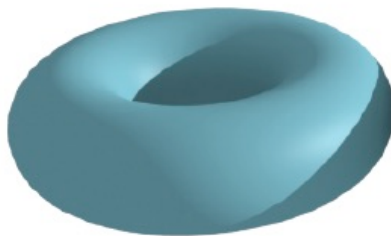




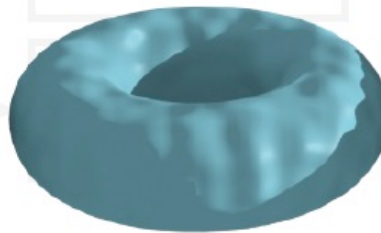
What is a shader?



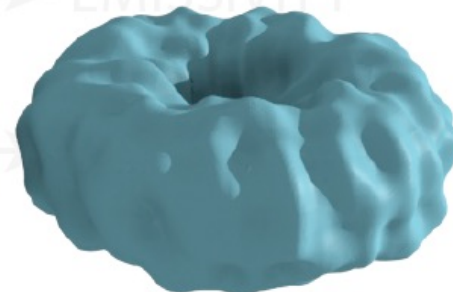
“displacement” or “vertex” shader



original



normal mapped



displaced

Super simple vertex shader

```
void main()  
{  
    gl_Position = gl_ProjectionMatrix * gl_ModelViewMatrix * gl_Vertex;  
}
```

```
void main(void)
{
    vec4 v = vec4(gl_Vertex);
    v.z = sin(5.0*v.x )*0.25;

    gl_Position = gl_ModelViewProjectionMatrix * v;
}
```



Vertex Shader

```
uniform vec3 lightDir;  
varying float intensity;  
void main()  
{  
    vec3 ld;  
    intensity = dot(lightDir,gl_Normal);  
    gl_Position = ftransform();  
}
```

Fragment Shader

```
varying float intensity;  
void main()  
{  
    vec4 color;  
    if (intensity > 0.95)  
        color = vec4(1.0,0.5,0.5,1.0);  
    else if (intensity > 0.5)  
        color = vec4(0.6,0.3,0.3,1.0);  
    else if (intensity > 0.25)  
        color = vec4(0.4,0.2,0.2,1.0);  
    else  
        color = vec4(0.2,0.1,0.1,1.0);  
    gl_FragColor = color;  
}
```



Simple diffuse lighting

The following vertex shader shows the GLSL code to achieve this.

```
void main() {  
  
    vec3 normal, lightDir;  
    vec4 diffuse;  
    float NdotL;  
  
    /* first transform the normal into eye space and normalize the result */  
    normal = normalize(gl_NormalMatrix * gl_Normal);  
  
    /* now normalize the light's direction. Note that according to the  
    OpenGL specification, the light is stored in eye space. Also since  
    we're talking about a directional light, the position field is actually  
    direction */  
    lightDir = normalize(vec3(gl_LightSource[0].position));  
  
    /* compute the cos of the angle between the normal and lights direction.  
    The light is directional so the direction is constant for every vertex.  
    Since these two are normalized the cosine is the dot product. We also  
    need to clamp the result to the [0,1] range. */  
    NdotL = max(dot(normal, lightDir), 0.0);  
  
    /* Compute the diffuse term */  
    diffuse = gl_FrontMaterial.diffuse * gl_LightSource[0].diffuse;  
  
    gl_FrontColor = NdotL * diffuse;  
  
    gl_Position = ftransform();  
}
```

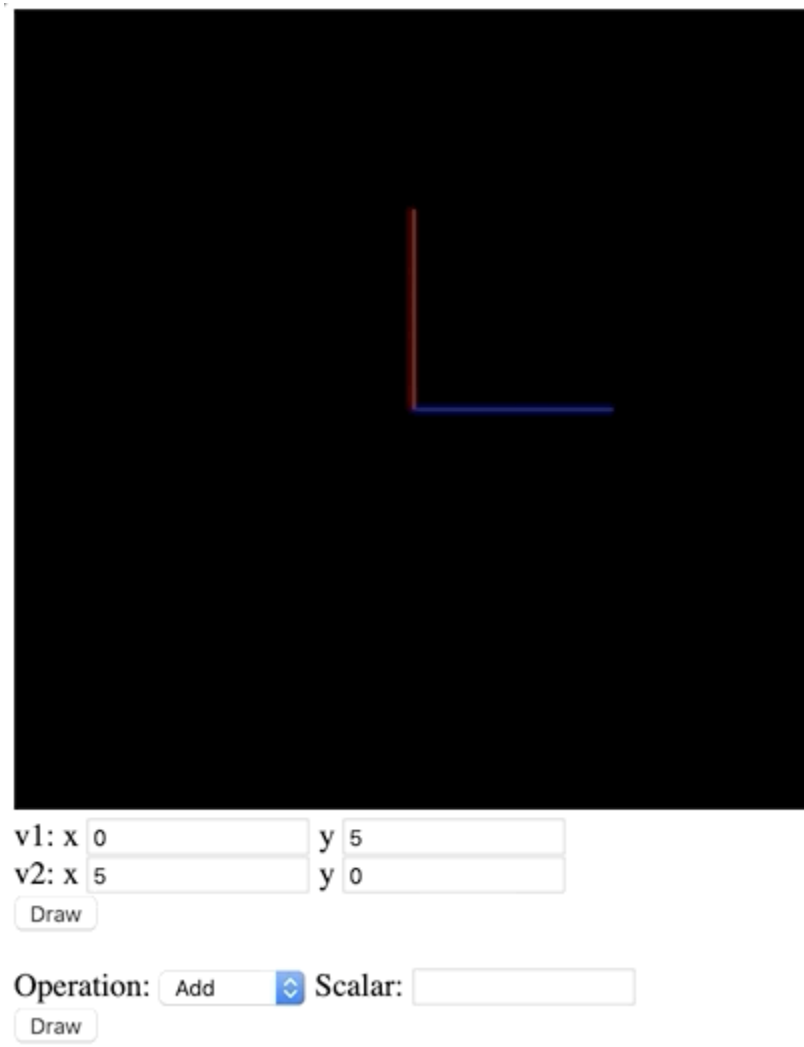
Now in the fragment shader all there is left to do is setting the fragments color, using the [varying](#) `gl_Color` variable.

```
void main()  
{  
    gl_FragColor = gl_Color;  
}
```

Assignment 0 and 1 Overview

(There are videos in Youtube Channel)

Assignment 0 – Intro HTML, Javascript, Linear Algebra



A0 – Detailed directions

Assignment 0: Vector Library

← → ↻ ↺

canvas.ucsc.edu/courses/36498/assignments/157754

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Assignment 0: Vector Library

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Related Items

SpeedGrader™

Download Submissions

0 out of 5 Submissions Graded

Videos:

- Assignment 0: Lab Section
https://www.youtube.com/watch?v=CkbO7_jYAmM&list=PLbyTU_tFlkcOUaZ9kLznqF6Eyyv4jUwgmS



Objectives:

Extend the matrix library provided by the textbook to support vector operations such as addition, subtraction, multiplication, cross product, dot product, etc. With this assignment, you will learn:

- How to create objected oriented graphics projects in Javascript.
- How to draw to a <canvas> element using a 2D context.
- Review fundamental concepts of Linear Algebra.

Introduction:

The textbook provides a matrix library called *cuon-matrix.js* which contains functions to create 4x4 matrices and operate with them. We will use this matrix later in this course for transforming (translate, weaver, for now we want to use this library for reviewing basic concepts of

A0 – Detailed grading rubric

Assignment 0: Vector Library

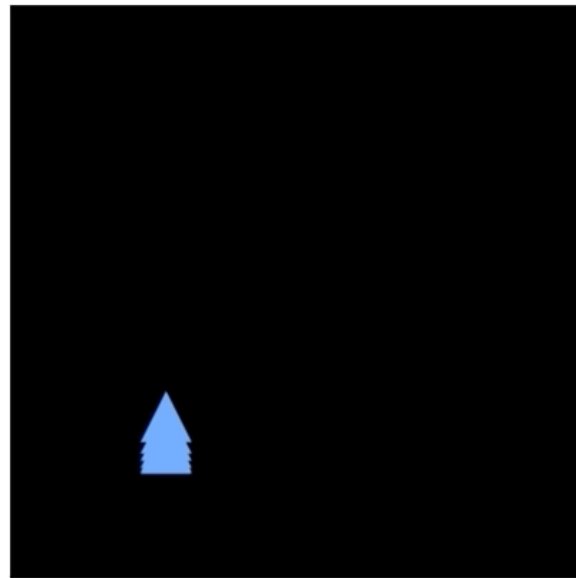
canvas.ucsc.edu/courses/36498/assignments/157754

UCSC

ASG0 Rubric

Criteria	Ratings		Pts
Setup the DrawRectangle example from the book with our matrix library.	1.0 pts Full Marks	0.0 pts No Marks	1.0 pts
Draw a red vector v1 on a black canvas instead of the blue rectangle. The origin of the vector should be the center of the canvas.	1.0 pts Full Marks	0.0 pts No Marks	1.0 pts
Add to your webpage an interface for the user to specify and draw the v1 vector.	2.0 pts Full Marks	0.0 pts No Marks	2.0 pts
Add to your webpage an interface for the user to specify and draw a second vector v2.	1.0 pts Full Marks	0.0 pts No Marks	1.0 pts
Add to your webpage an interface for the user to perform and visualize the results of add, sub, div and mul operations.	2.0 pts Full Marks	0.0 pts No Marks	2.0 pts
Add to your webpage an interface for the user to perform and visualize the results of magnitude and normalize operations.	1.0 pts Full Marks	0.0 pts No Marks	1.0 pts

Assignment 1 – WebGL, Paint



Clear Canvas

Drawing Mode:

Squares

Triangles

Circles

Shape Color:

Red



Green



Blue



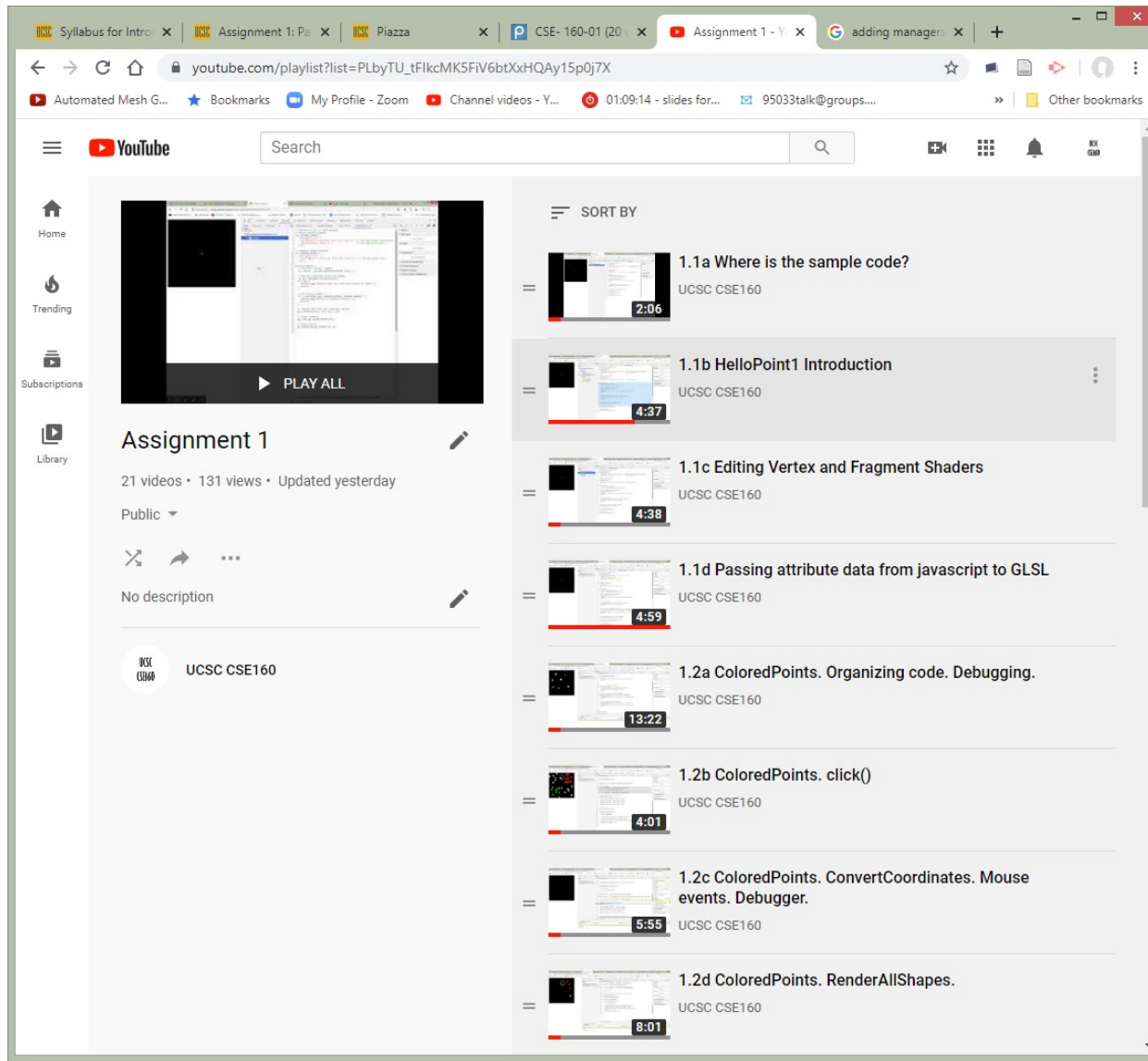
Shape Size:



(Circles) Segment Count:



Detailed help videos (starting with A1)



The screenshot shows a web browser window with multiple tabs open, including 'Syllabus for Intro...', 'Assignment 1: P...', 'Piazza', 'CSE- 160-01 (20...', 'Assignment 1 - Y...', and 'adding managers...'. The active tab is a YouTube playlist page for 'Assignment 1' by the channel 'UCSC CSE160'. The playlist is public, has 21 videos, 131 views, and was updated yesterday. The video thumbnails show code editors and terminal windows. The video titles and durations are listed on the right side of the page.

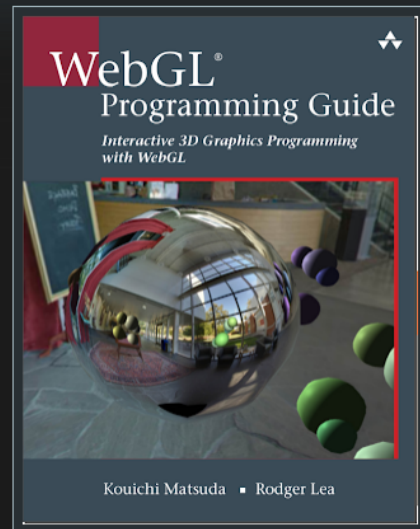
Assignment 1
21 videos • 131 views • Updated yesterday
Public
No description

UCSC CSE160

SORT BY

- 1.1a Where is the sample code? UCSC CSE160 2:06
- 1.1b HelloPoint1 Introduction UCSC CSE160 4:37
- 1.1c Editing Vertex and Fragment Shaders UCSC CSE160 4:38
- 1.1d Passing attribute data from javascript to GLSL UCSC CSE160 4:59
- 1.2a ColoredPoints. Organizing code. Debugging. UCSC CSE160 13:22
- 1.2b ColoredPoints. click() UCSC CSE160 4:01
- 1.2c ColoredPoints. ConvertCoordinates. Mouse events. Debugger. UCSC CSE160 5:55
- 1.2d ColoredPoints. RenderAllShapes. UCSC CSE160 8:01

Detailed WebGL examples



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From **Amazon**
From **Addison-Wesley Professional** directly

Kouichi Matsuda

Rodger Lea
Publications
Research
Bio

Contact us at: webql.pg@gmail.com

Welcome

This web site acts as the primary location for the example code in the book as well as a place for us to provide updates and new materials as we get feedback.

This book covers the WebGL 1.0 API along with all related JavaScript functions. You will learn how HTML, JavaScript, and WebGL are related, how to set up and run WebGL applications, and how to incorporate sophisticated 3D program "shaders" under the control of JavaScript. The book details how to write vertex and fragment shaders, how to implement advanced rendering techniques such as per-pixel lighting and shadowing, and basic interaction techniques such as selecting 3D objects. Each chapter develops a number of working, fully functional WebGL applications and explains key WebGL features through these examples. After finishing the book, you will be ready to write WebGL applications that fully harness the programmable power of web browsers and the underlying graphics hardware.

Book examples by chapter

Full text example chapter: [Chapter 3](#)

- **Chapter 1:** Overview of WebGL
- **Chapter 2:** Your First Step with WebGL
- **Chapter 3:** Drawing and Transforming Triangles
- **Chapter 4:** More transformations and Basic Animation
- **Chapter 5:** Using Colors and Texture Images
- **Chapter 6:** The OpenGL ES Shading Language (GLSL ES)
- **Chapter 7:** Toward the 3D World
- **Chapter 8:** Lighting Objects
- **Chapter 9:** Hierarchical Objects
- **Chapter 10:** Advanced Techniques
- **Appendices:** A, B, C, D, E, F, G, H
- **Extras:** extra examples

- **Download all examples**

Some useful links

Errata an updated list of mistakes

Recent site activity

WebGL Programming
Guide. Matsuda & Lea
edited by Rodger Lea

WebGL-PG Errata
edited by Rodger Lea

1. Overview of WebGL

WebGL-PG Errata
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WebGL Programming
Guide. Matsuda & Lea
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Administrative

Q&A

End