

Viewing

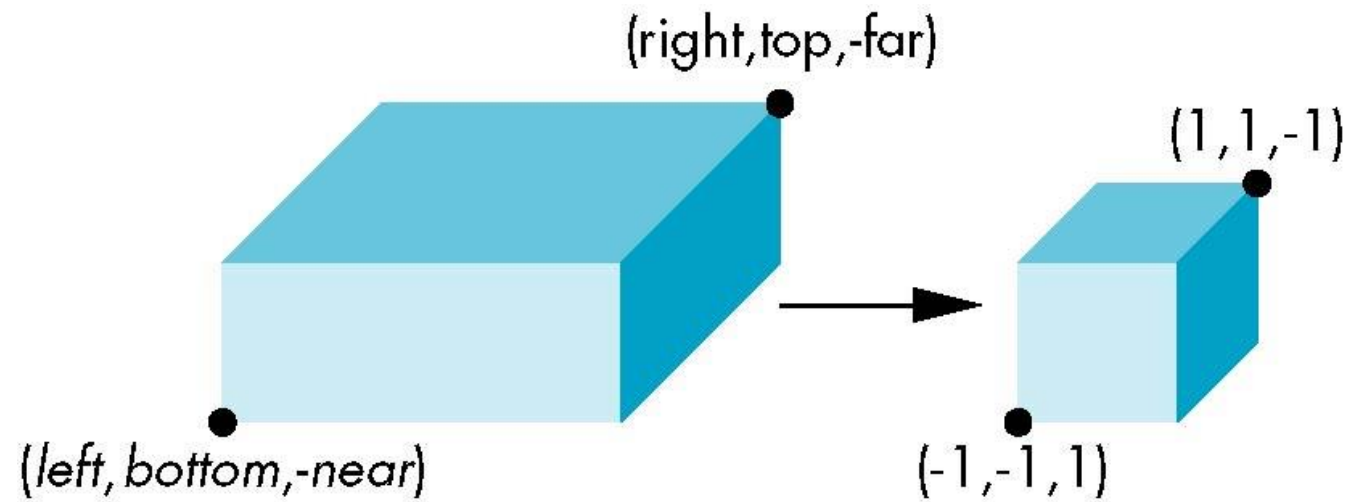
9TH WEEK, 2021



Orthogonal Normalization

`ortho(left, right, bottom, top, near, far)`

- Normalization \Rightarrow find transformation to convert specified clipping volume to default



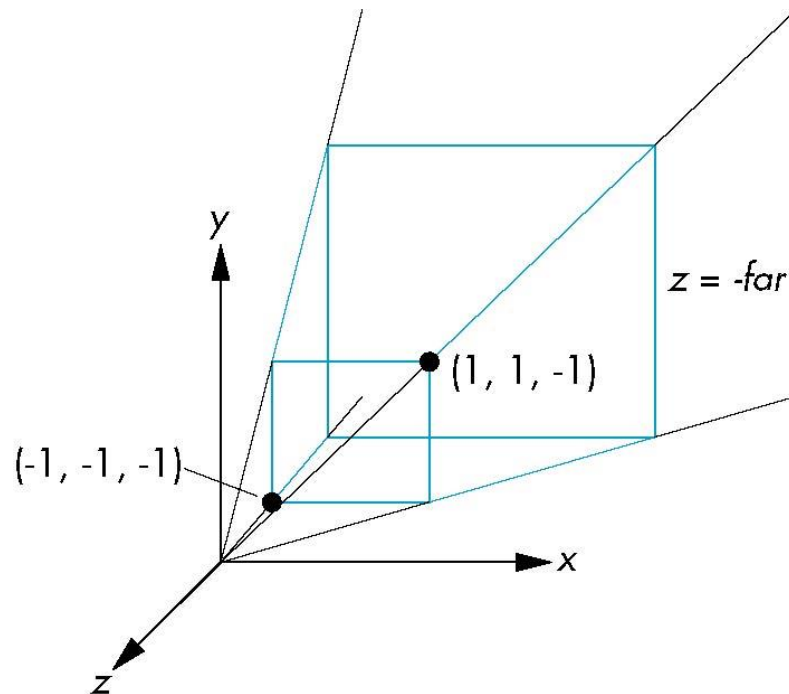
Orthogonal Matrix

- Two steps
 - Move center to origin: $T(-(left+right)/2, -(bottom+top)/2, (near+far)/2))$
 - Scale to have sides of length 2: $S(2/(left-right), 2/(top-bottom), 2/(near-far))$

$$\mathbf{P} = \mathbf{ST} = \begin{bmatrix} \frac{2}{right - left} & 0 & 0 & -\frac{right + left}{right - left} \\ 0 & \frac{2}{top - bottom} & 0 & -\frac{top + bottom}{top - bottom} \\ 0 & 0 & \frac{2}{near - far} & \frac{far + near}{far - near} \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Simple Perspective

- Consider a simple perspective with the COP at the origin, the near clipping plane at $z = -1$, and a 90-degree field of view determined by the planes $x = \pm z$, $y = \pm z$



Perspective Matrices

- Simple projection matrix in homogeneous coordinates

$$\mathbf{M} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & -1 & 0 \end{bmatrix}$$

- Note that this matrix is independent of the far clipping plane

Generalization

$$\mathbf{N} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & \alpha & \beta \\ 0 & 0 & -1 & 0 \end{bmatrix}$$

- after perspective division, the point $(x, y, z, 1)$ goes to

$$x'' = x/z$$

$$y'' = y/z$$

$$z'' = -(\alpha + \beta/z)$$

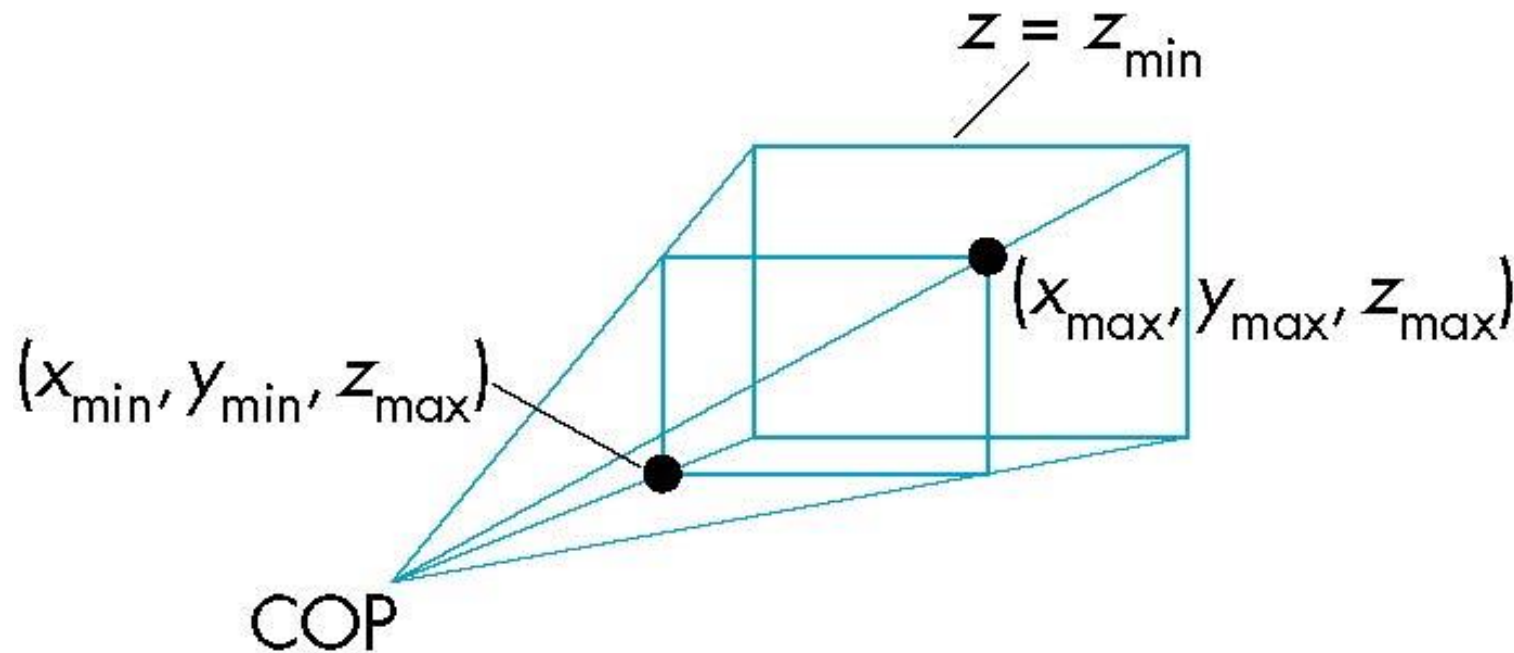
- which projects orthogonally to the desired point regardless of α and β

Picking α and β

- If we pick:
$$\alpha = \frac{\text{near} + \text{far}}{\text{far} - \text{near}}$$
$$\beta = \frac{2\text{near} * \text{far}}{\text{near} - \text{far}}$$
 - the near plane is mapped to $z = -1$
 - the far plane is mapped to $z = 1$
 - and the sides are mapped to $x = \pm 1, y = \pm 1$
- Hence the new clipping volume is the default clipping volume

WebGL Perspective

- **gl.frustum** allows for an unsymmetric viewing frustum (although **gl.perspective** does not)



Perspective Matrices

- frustum

$$\mathbf{P} = \begin{bmatrix} \frac{2 * near}{right - left} & 0 & \frac{right - left}{right - left} & 0 \\ 0 & \frac{2 * near}{top - bottom} & \frac{top + bottom}{top - bottom} & 0 \\ 0 & 0 & -\frac{far + near}{far - near} & -\frac{2 * far * near}{far - near} \\ 0 & 0 & -1 & 0 \end{bmatrix}$$

- perspective

$$\mathbf{P} = \begin{bmatrix} \frac{near}{right} & 0 & 0 & 0 \\ 0 & \frac{near}{top} & 0 & 0 \\ 0 & 0 & -\frac{far + near}{far - near} & -\frac{2 * far * near}{far - near} \\ 0 & 0 & -1 & 0 \end{bmatrix}$$

```

<> view.html x JS view.js JS MV.js
C: > Users > Sun-Jeong Kim > Desktop > CG > <> view.html > html > head > script#vertex-shader
1  <!DOCTYPE html>
2  <html>
3    <head>
4      <title>학번 이름</title>
5      <script id="vertex-shader" type="x-shader/x-vertex">
6        attribute vec4 vPosition;
7        attribute vec4 vColor;
8        uniform mat4 modelViewMatrix;
9        uniform mat4 projectionMatrix;
10       varying vec4 fColor;
11
12       void main()
13       {
14         gl_Position = projectionMatrix * modelViewMatrix * vPosition;
15         fColor = vColor;
16       }
17     </script>
18
19     <script id="fragment-shader" type="x-shader/x-fragment">
20       precision mediump float;
21       varying vec4 fColor;
22
23       void main() {
24         gl_FragColor = fColor;
25       }
26     </script>
27
28     <script type="text/javascript" src="Common/webgl-utils.js"></script>
29     <script type="text/javascript" src="Common/initShaders.js"></script>
30     <script type="text/javascript" src="Common/MV.js"></script>
31     <script type="text/javascript" src="trackball.js"></script>
32     <script type="text/javascript" src="view.js"></script>
33   </head>
34   <body>
35     <canvas id="gl-canvas" width="512" height="512">

```



view.html - Visual Studio Code

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view.html x JS view.js JS MV.js

C: > Users > Sun-Jeong Kim > Desktop > CG > <> view.html > html > head > script#vertex-shader

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13      {
14          gl_Position = projectionMatrix * modelViewMatrix * vPosition;
15          fColor = vColor;
16      }
17  </script>
18
19  <script id="fragment-shader" type="x-shader/x-fragment">
20  precision mediump float;
21  varying vec4 fColor;
22
23  void main() {
24      gl_FragColor = fColor;
25  }
26  </script>
27
28  <script type="text/javascript" src="Common/webgl-utils.js"></script>
29  <script type="text/javascript" src="Common/initShaders.js"></script>
30  <script type="text/javascript" src="Common/MV.js"></script>
31  <script type="text/javascript" src="trackball.js"></script>
32  <script type="text/javascript" src="view.js"></script>
33  </head>
34  <body>
35      <canvas id="gl-canvas" width="512" height="512">
36          Oops... your browser doesn't support the HTML5 canvas element!
37      </canvas><br>
38      <div style="width:512px; text-align:center;">
39          <button id="left">◀</button>
40          <button id="up">▲</button>
41          <button id="right">▶</button><br>
42          <button id="down">▼</button>
43      </div>
44  </body>
45  </html>
```

view.js

trackball.js

Common

webgl-utils.js

initShaders.js

MV.js

view.js

0 0 0

Ln 14, Col 73 Spaces: 4 UTF-8 CRLF HTML

```

view.html JS view.js JS MV.js
C: > Users > Sun-Jeong Kim > Desktop > CG > JS view.js > render
1  var gl;
2  var points = [];
3  var colors = [];
4
5  var modelViewMatrix, projectionMatrix;
6  var modelViewMatrixLoc, projectionMatrixLoc;
7  var eye = vec3(0.0, 0.0, 1.0);
8  var at = vec3(0.0, 0.0, 0.0);
9  var up = vec3(0.0, 1.0, 0.0);
10
11 var trballMatrix = mat4(1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1);
12
13 window.onload = function init()
14 {
15     var canvas = document.getElementById("gl-canvas");
16
17     gl = WebGLUtils.setupWebGL(canvas);
18     if( !gl ) {
19         alert("WebGL isn't available!");
20     }
21
22     generateColorCube();
23
24     // virtual trackball
25     var trball = trackball(canvas.width, canvas.height);
26     var mouseDown = false;
27
28     canvas.addEventListener("mousedown", function(event) {
29         trball.start(event.clientX, event.clientY);
30
31         mouseDown = true;
32     });
33
34     canvas.addEventListener("mouseup", function(event) {
35         mouseDown = false;

```



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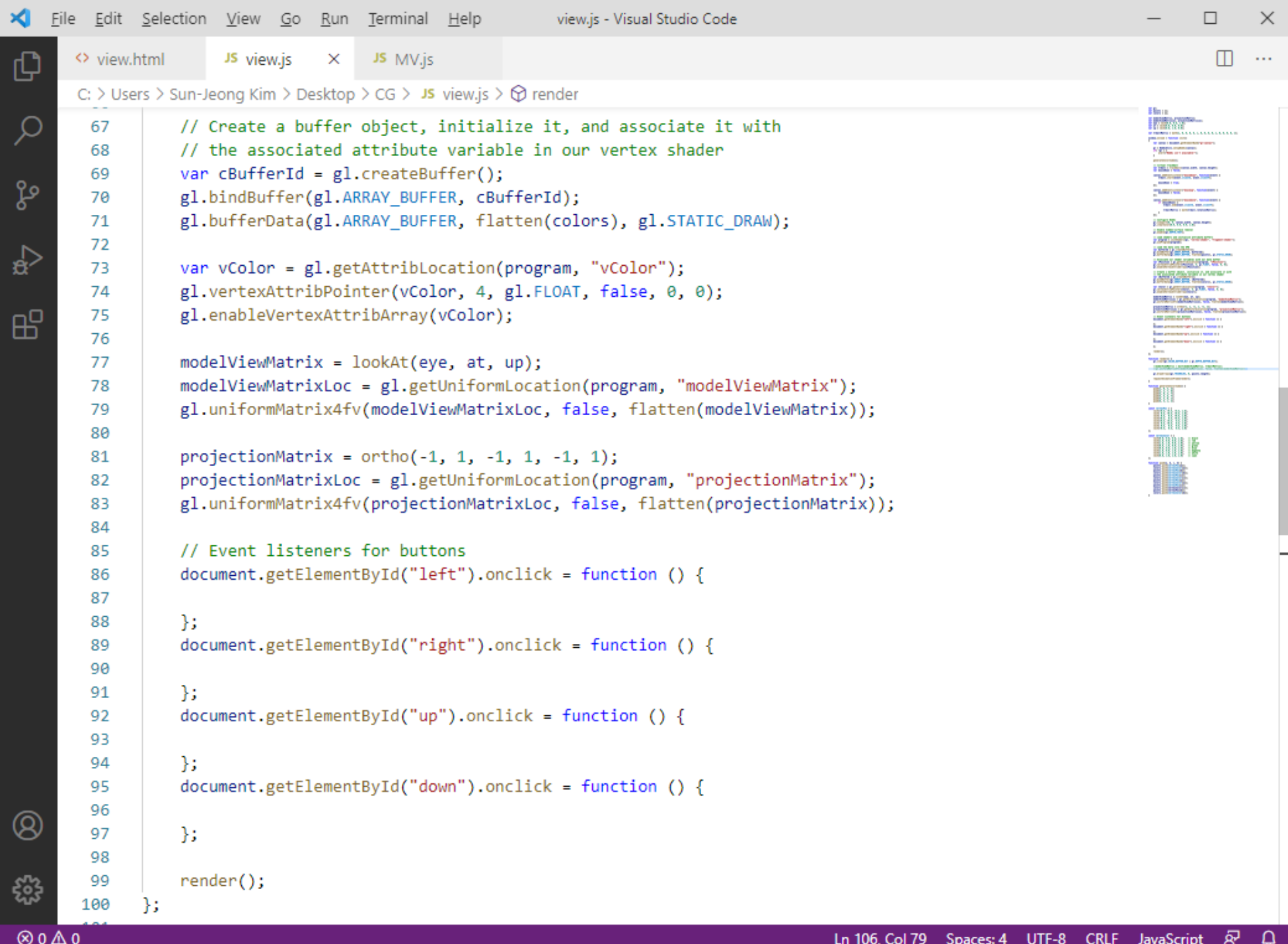
view.js - Visual Studio Code

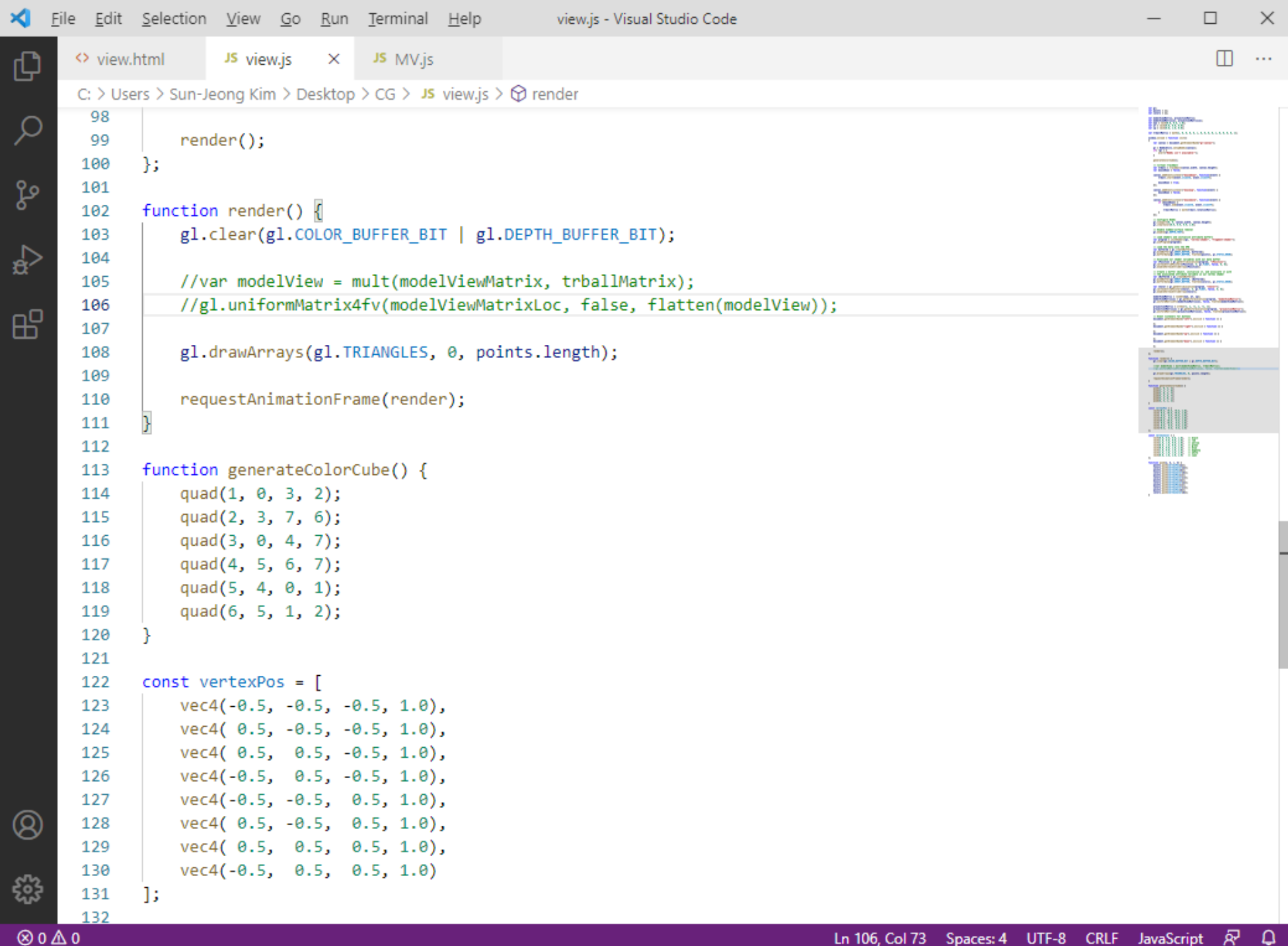
view.html JS view.js JS MV.js

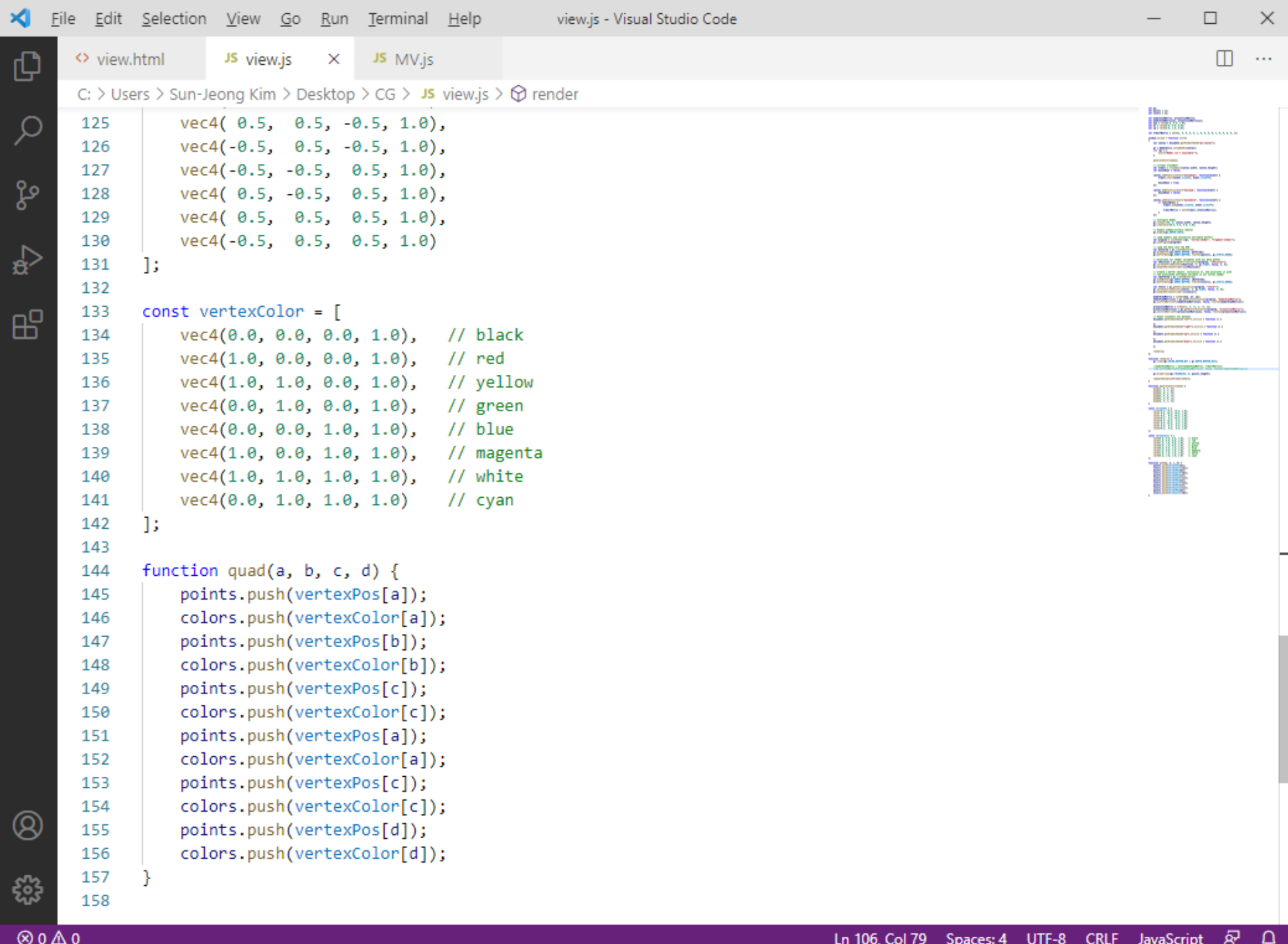
C: > Users > Sun-Jeong Kim > Desktop > CG > JS view.js > render

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34 canvas.addEventListener("mouseup", function(event) {
35     mouseDown = false;
36 });
37
38 canvas.addEventListener("mousemove", function(event) {
39     if (mouseDown) {
40         trball.end(event.clientX, event.clientY);
41
42         trballMatrix = mat4(trball.rotationMatrix);
43     }
44 });
45
46 // Configure WebGL
47 gl.viewport(0, 0, canvas.width, canvas.height);
48 gl.clearColor(0.9, 0.9, 0.9, 1.0);
49
50 // Enable hidden-surface removal
51 gl.enable(gl.DEPTH_TEST);
52
53 // Load shaders and initialize attribute buffers
54 var program = initShaders(gl, "vertex-shader", "fragment-shader");
55 gl.useProgram(program);
56
57 // Load the data into the GPU
58 var bufferId = gl.createBuffer();
59 gl.bindBuffer(gl.ARRAY_BUFFER, bufferId);
60 gl.bufferData(gl.ARRAY_BUFFER, flatten(points), gl.STATIC_DRAW);
61
62 // Associate our shader variables with our data buffer
63 var vPosition = gl.getAttribLocation(program, "vPosition");
64 gl.vertexAttribPointer(vPosition, 4, gl.FLOAT, false, 0, 0);
65 gl.enableVertexAttribArray(vPosition);
66
67 // Create a buffer object, initialize it, and associate it with
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view.html

JS view.js

JS MV.js

X

C: > Users > Sun-Jeong Kim > Desktop > CG > Common > JS MV.js > ...

```

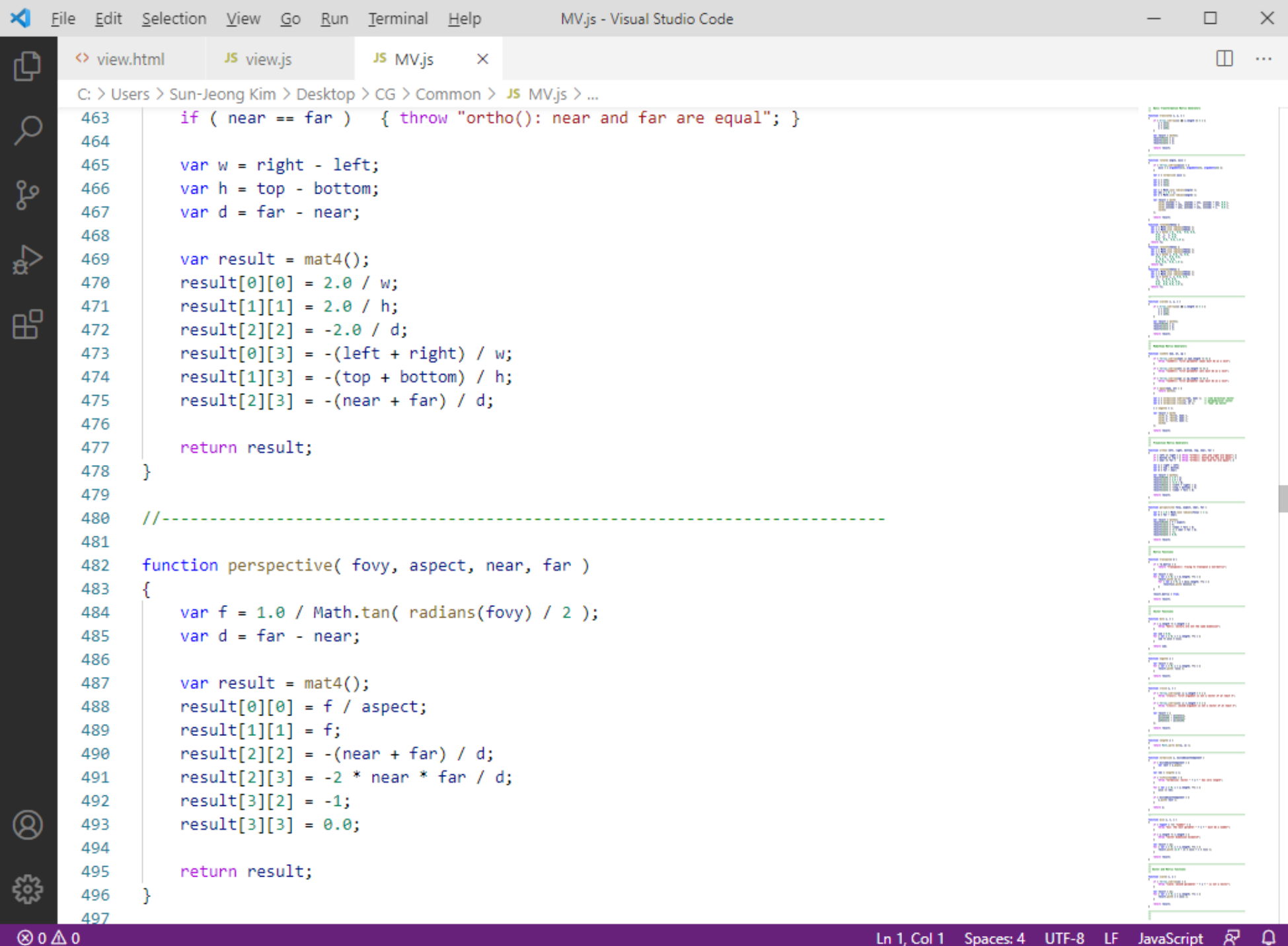
454 //-----
455 //
456 // Projection Matrix Generators
457 //
458
459 function ortho( left, right, bottom, top, near, far )
460 {
461     if ( left == right ) { throw "ortho(): left and right are equal"; }
462     if ( bottom == top ) { throw "ortho(): bottom and top are equal"; }
463     if ( near == far ) { throw "ortho(): near and far are equal"; }
464
465     var w = right - left;
466     var h = top - bottom;
467     var d = far - near;
468
469     var result = mat4();
470     result[0][0] = 2.0 / w;
471     result[1][1] = 2.0 / h;
472     result[2][2] = -2.0 / d;
473     result[0][3] = -(left + right) / w;
474     result[1][3] = -(top + bottom) / h;
475     result[2][3] = -(near + far) / d;
476
477     return result;
478 }
479
480 //-----
481
482 function perspective( fovy, aspect, near, far )
483 {
484     var f = 1.0 / Math.tan( radians(fovy) / 2 );
485     var d = far - near;
486
487     var result = mat4();
488     result[0][0] = f / aspect;

```

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Ln 1, Col 1 Spaces: 4 UTF-8 LF JavaScript

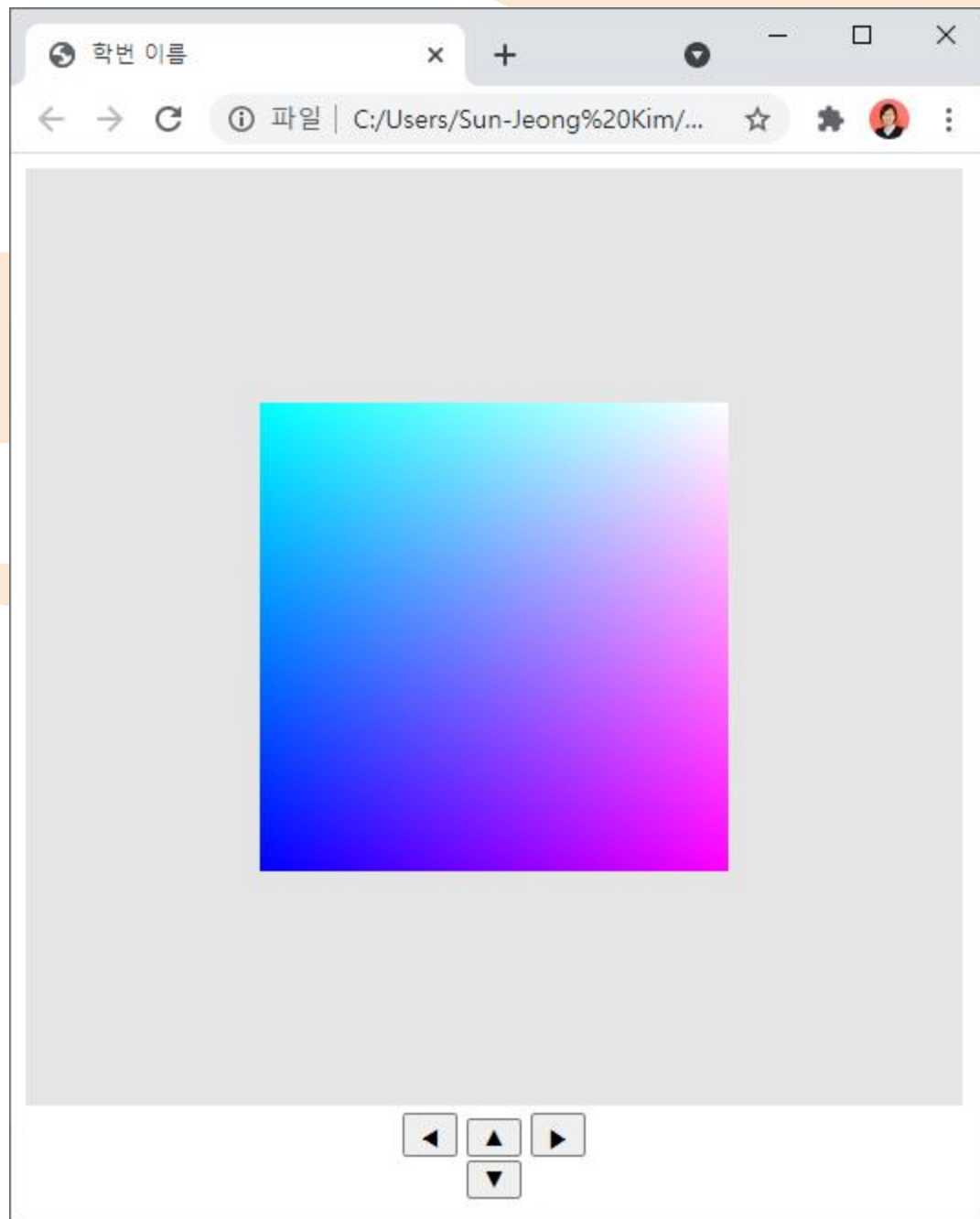
17



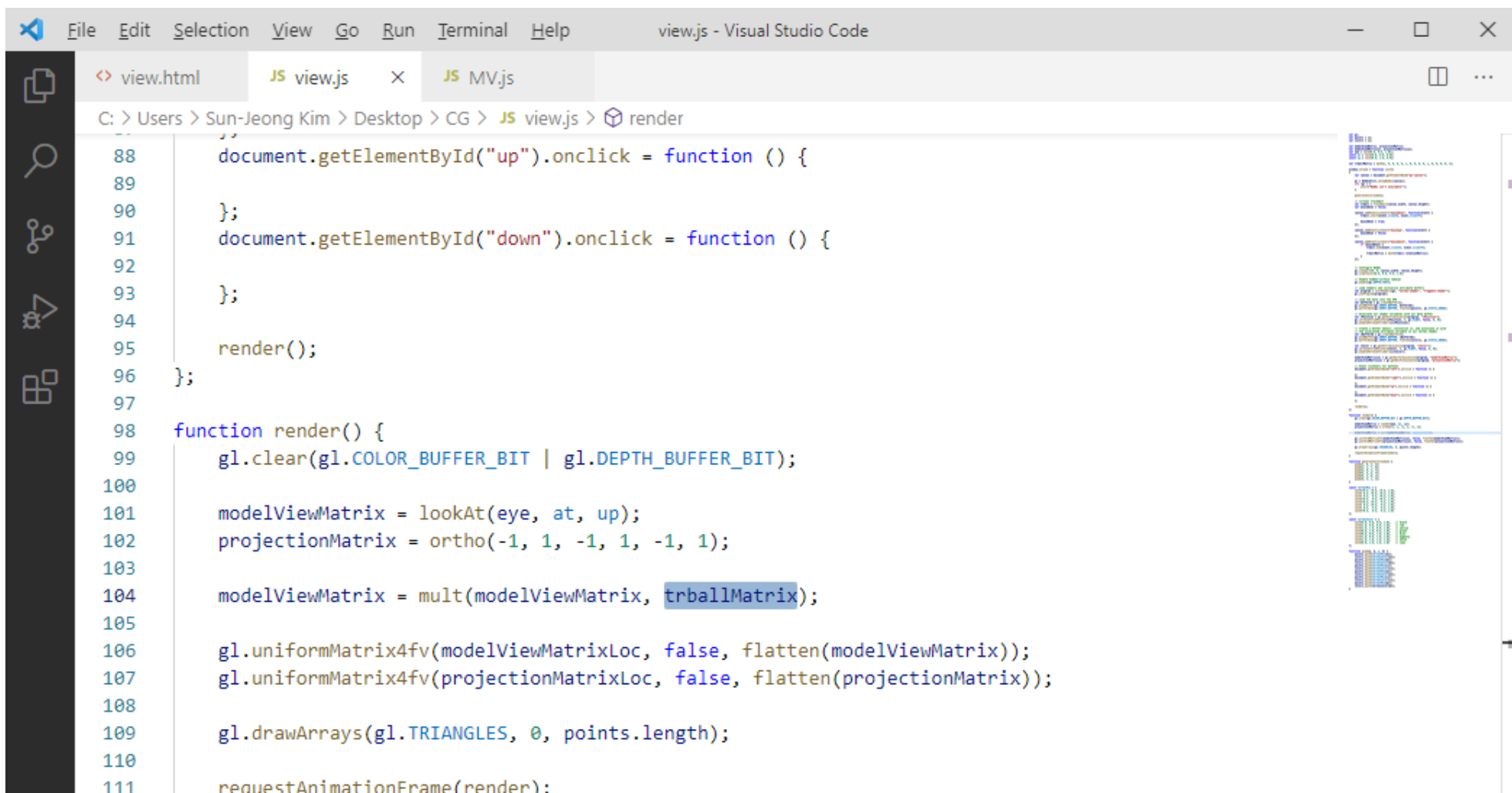
```

view.html JS view.js JS MV.js X
C: > Users > Sun-Jeong Kim > Desktop > CG > Common > JS MV.js > ...
419
420 function lookAt( eye, at, up )
421 {
422     if ( !Array.isArray(eye) || eye.length !== 3 ) {
423         throw "lookAt(): first parameter [eye] must be an a vec3";
424     }
425
426     if ( !Array.isArray(at) || at.length !== 3 ) {
427         throw "lookAt(): first parameter [at] must be an a vec3";
428     }
429
430     if ( !Array.isArray(up) || up.length !== 3 ) {
431         throw "lookAt(): first parameter [up] must be an a vec3";
432     }
433
434     if ( equal(eye, at) ) {
435         return mat4();
436     }
437
438     var v = normalize( subtract(at, eye) ); // view direction vector
439     var n = normalize( cross(v, up) );     // perpendicular vector
440     var u = normalize( cross(n, v) );     // "new" up vector
441
442     v = negate( v );
443
444     var result = mat4(
445         vec4( n, -dot(n, eye) ),
446         vec4( u, -dot(u, eye) ),
447         vec4( v, -dot(v, eye) ),
448         vec4()
449     );
450
451     return result;
452 }
453

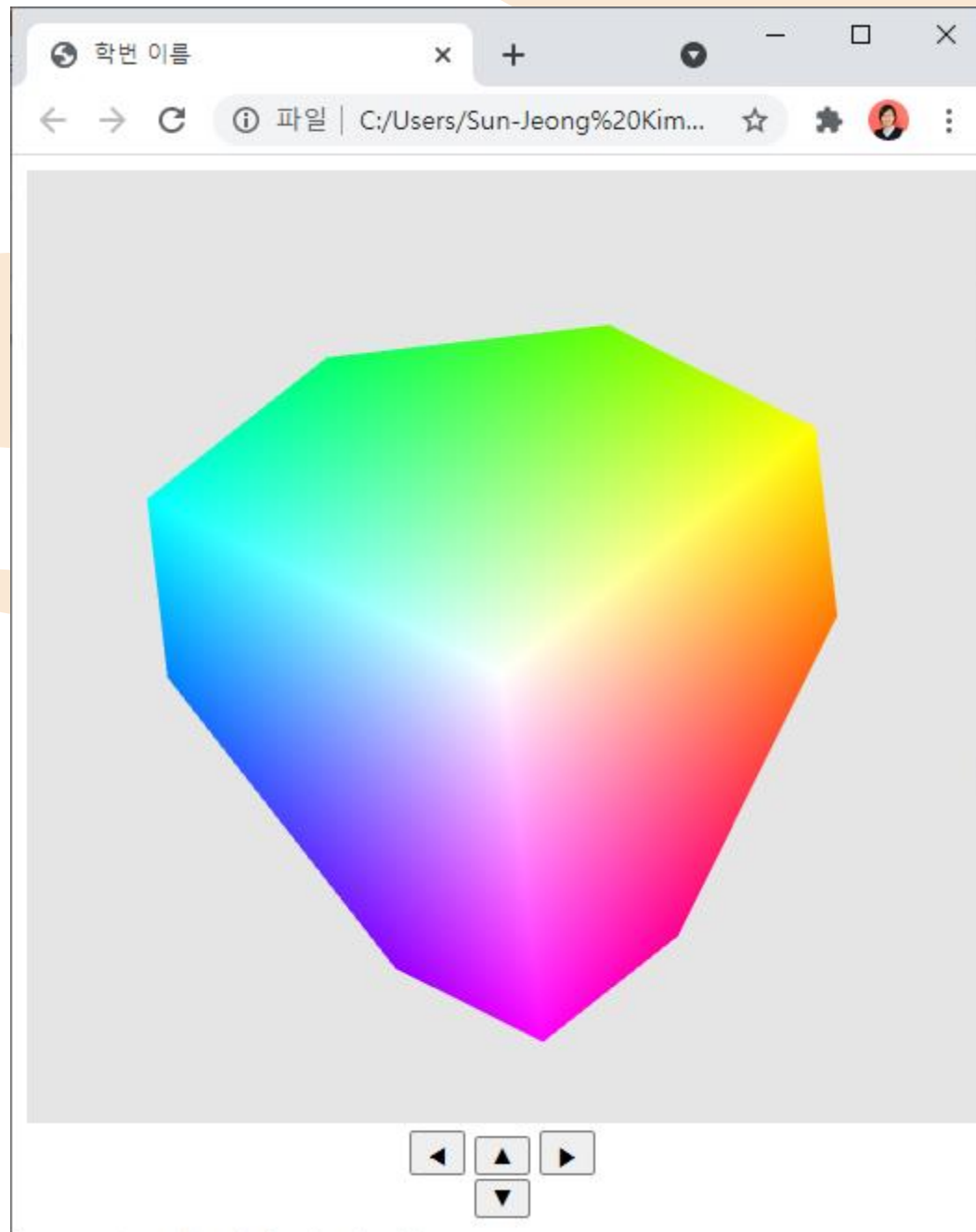
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Rotation with a Quaternion



```
view.js - Visual Studio Code
view.html JS view.js JS MV.js
C: > Users > Sun-Jeong Kim > Desktop > CG > JS view.js > render
88 document.getElementById("up").onclick = function () {
89
90 };
91 document.getElementById("down").onclick = function () {
92
93 };
94
95 render();
96 };
97
98 function render() {
99   gl.clear(gl.COLOR_BUFFER_BIT | gl.DEPTH_BUFFER_BIT);
100
101   modelViewMatrix = lookAt(eye, at, up);
102   projectionMatrix = ortho(-1, 1, -1, 1, -1, 1);
103
104   modelViewMatrix = mult(modelViewMatrix, trballMatrix);
105
106   gl.uniformMatrix4fv(modelViewMatrixLoc, false, flatten(modelViewMatrix));
107   gl.uniformMatrix4fv(projectionMatrixLoc, false, flatten(projectionMatrix));
108
109   gl.drawArrays(gl.TRIANGLES, 0, points.length);
110
111   requestAnimationFrame(render);
```



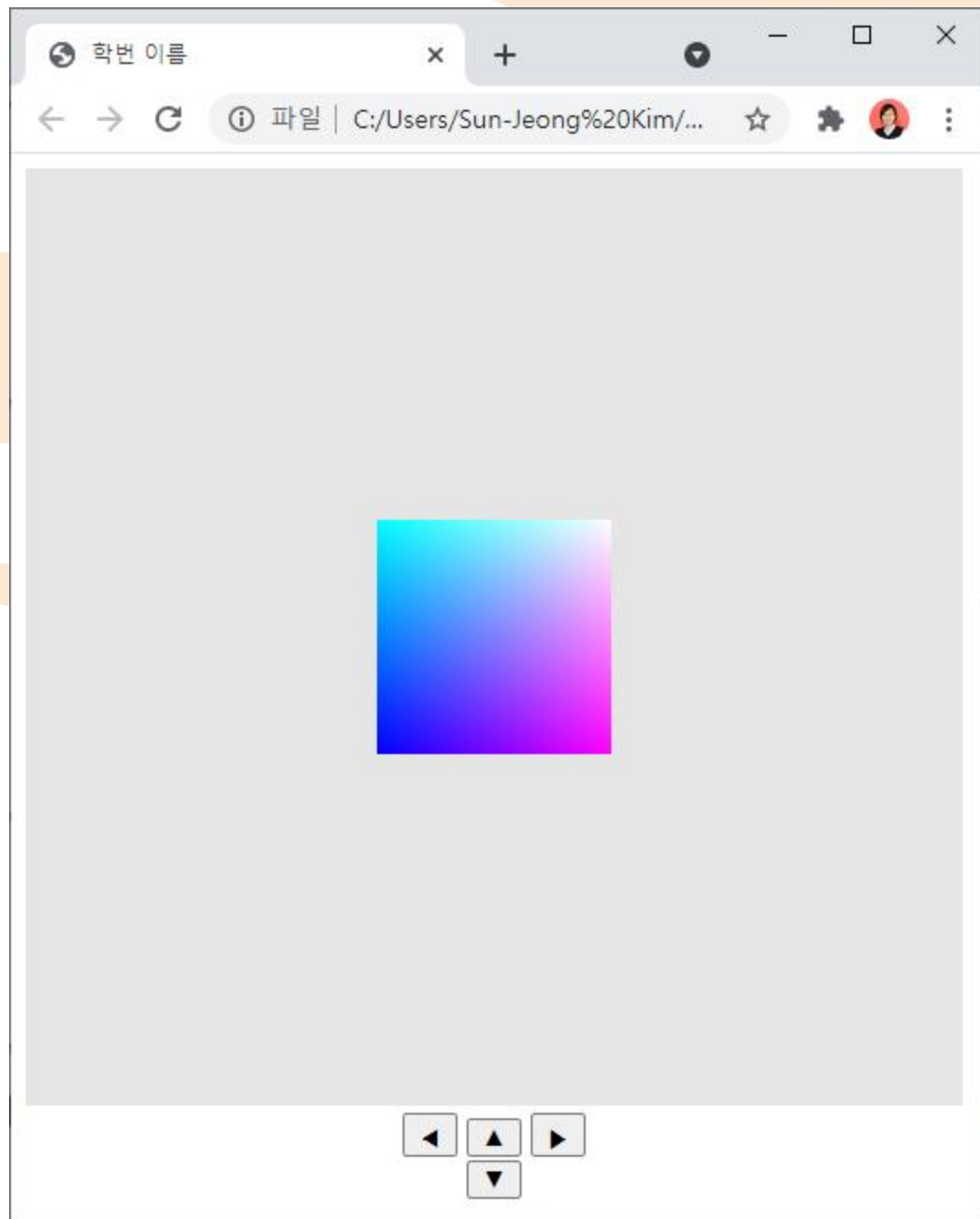
view.js - Visual Studio Code

view.html JS view.js JS MV.js

C: > Users > Sun-Jeong Kim > Desktop > CG > JS view.js > init

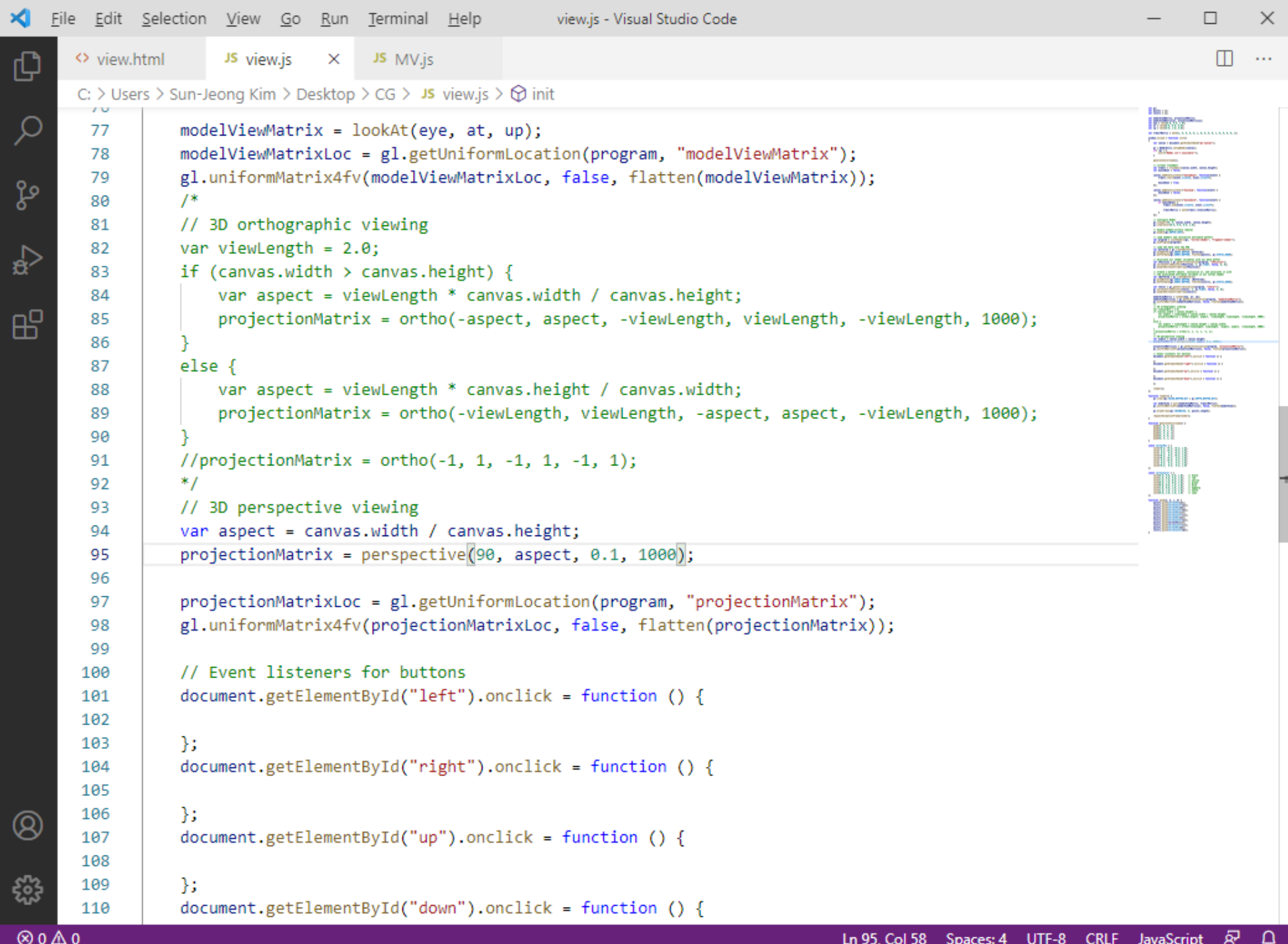
```
77 modelViewMatrix = lookAt(eye, at, up);
78 modelViewMatrixLoc = gl.getUniformLocation(program, "modelViewMatrix");
79 gl.uniformMatrix4fv(modelViewMatrixLoc, false, flatten(modelViewMatrix));
80
81 // 3D orthographic viewing
82 var viewLength = 2.0;
83 if (canvas.width > canvas.height) {
84     var aspect = viewLength * canvas.width / canvas.height;
85     projectionMatrix = ortho(-aspect, aspect, -viewLength, viewLength, -viewLength, 1000);
86 }
87 else {
88     var aspect = viewLength * canvas.height / canvas.width;
89     projectionMatrix = ortho(-viewLength, viewLength, -aspect, aspect, -viewLength, 1000);
90 }
91 //projectionMatrix = ortho(-1, 1, -1, 1, -1, 1);
92 projectionMatrixLoc = gl.getUniformLocation(program, "projectionMatrix");
93 gl.uniformMatrix4fv(projectionMatrixLoc, false, flatten(projectionMatrix));
94
95 // Event listeners for buttons
96 document.getElementById("left").onclick = function () {
97
98 };
99 document.getElementById("right").onclick = function () {
100
101 };
102 document.getElementById("up").onclick = function () {
103
104 };
105 document.getElementById("down").onclick = function () {
106
107 };
108
109 render();
110 };
```

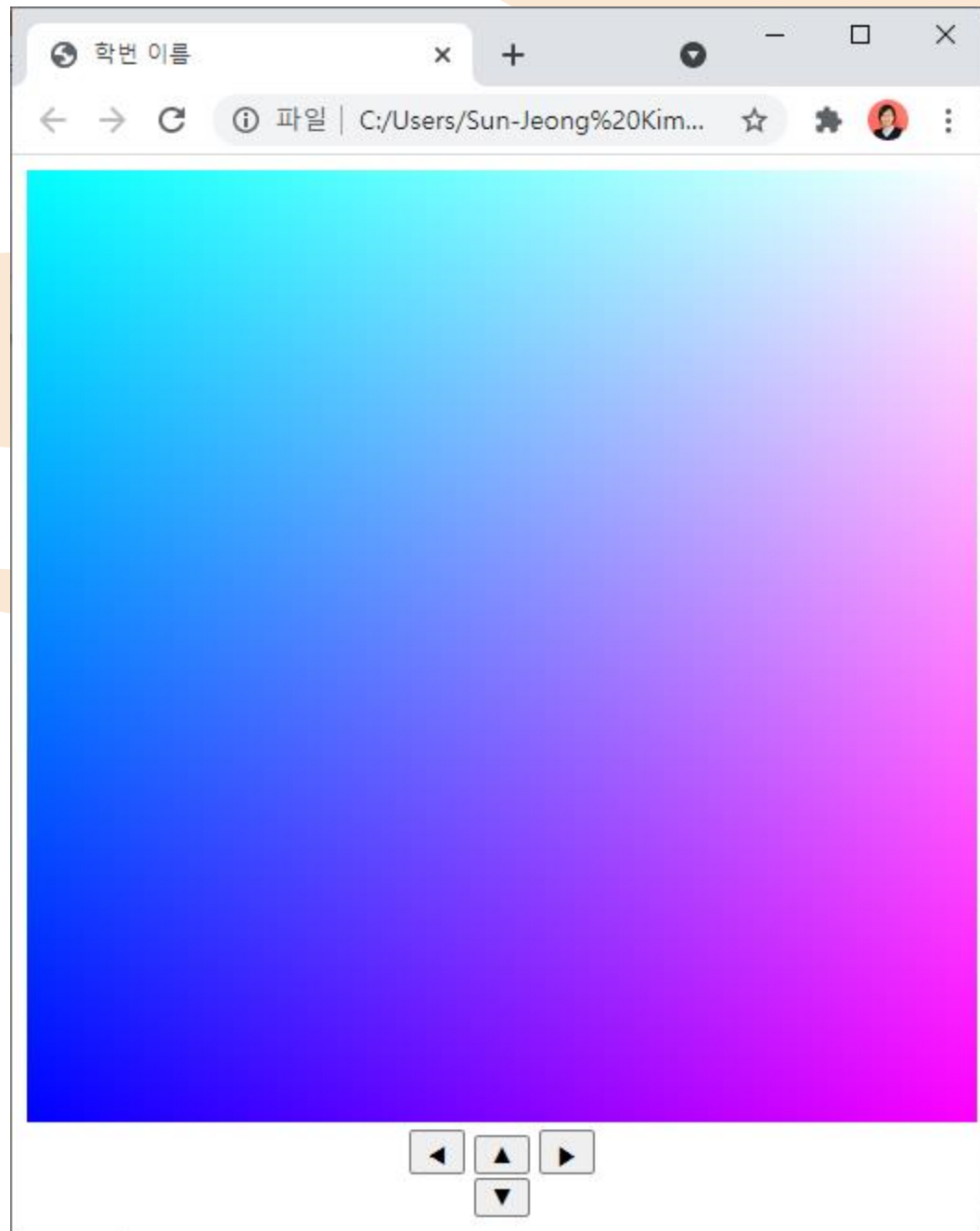
Ln 89, Col 93 Spaces: 4 UTF-8 CRLF JavaScript



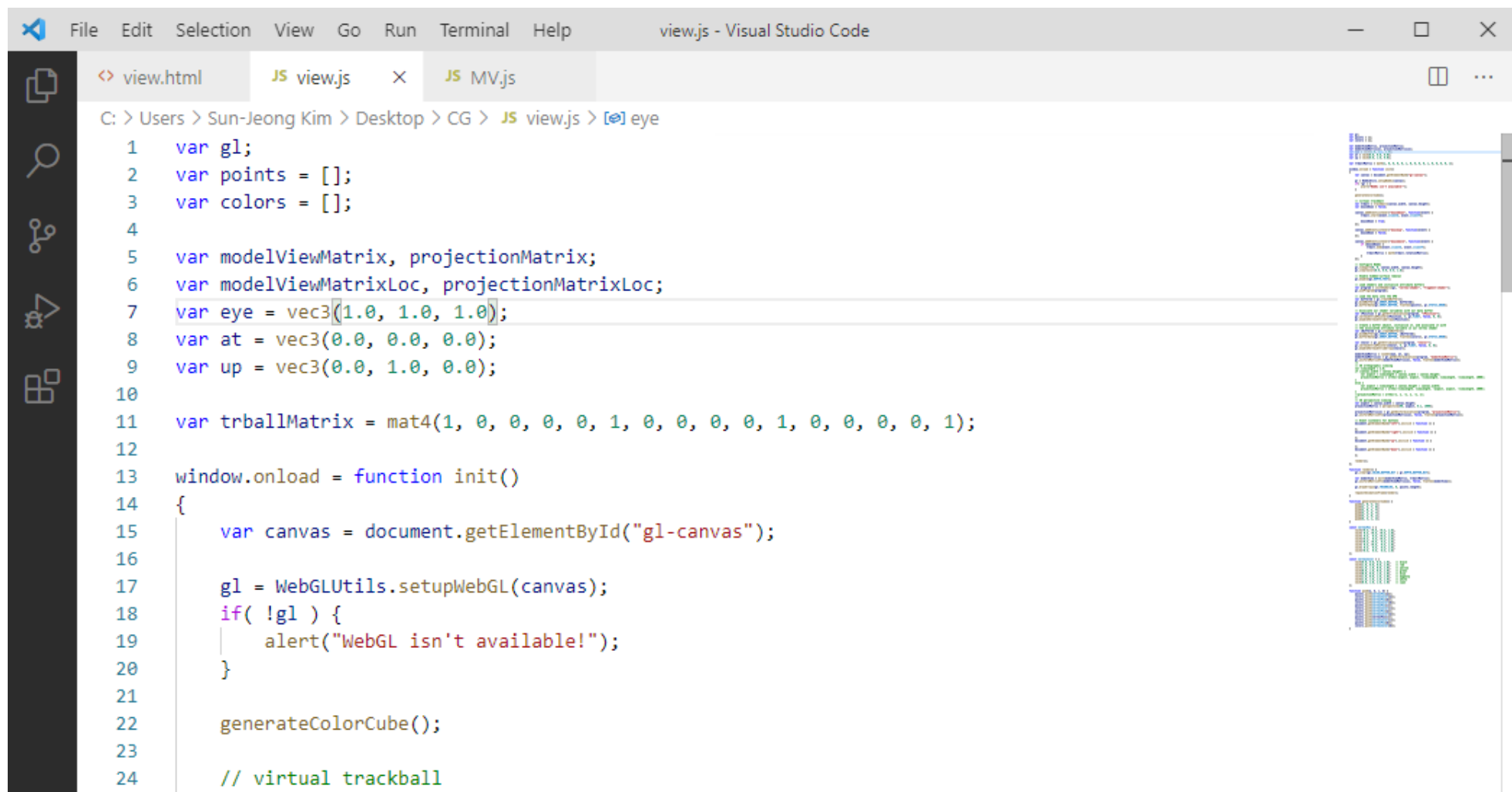
연습 문제 (1)

- ortho() 함수의 left, right, bottom, top의 값을 변경해보고, 그 의미를 파악해 보시오.
 - 예) viewLength = 1.0; 또는 viewLength = 3.0;

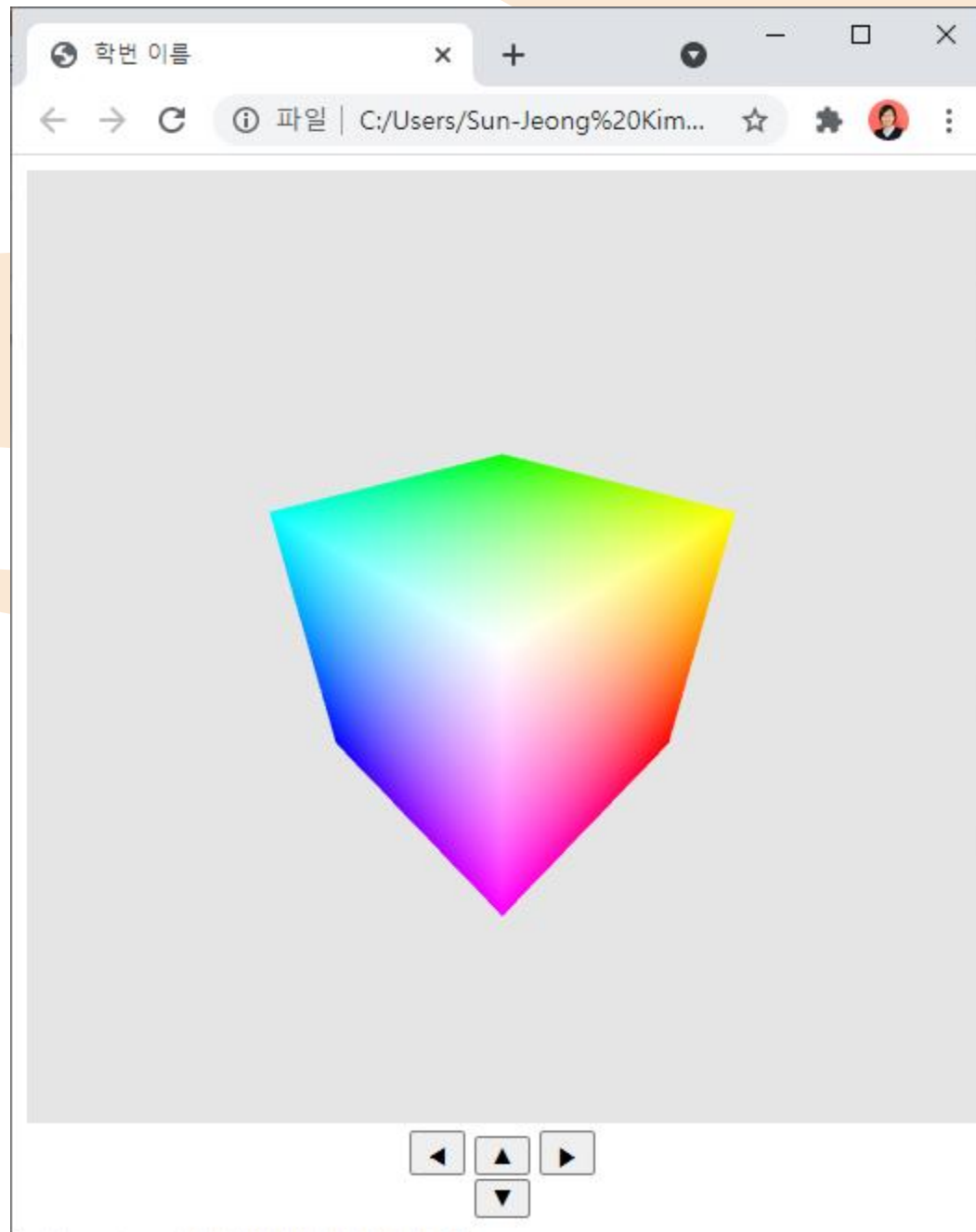




Locating the Camera

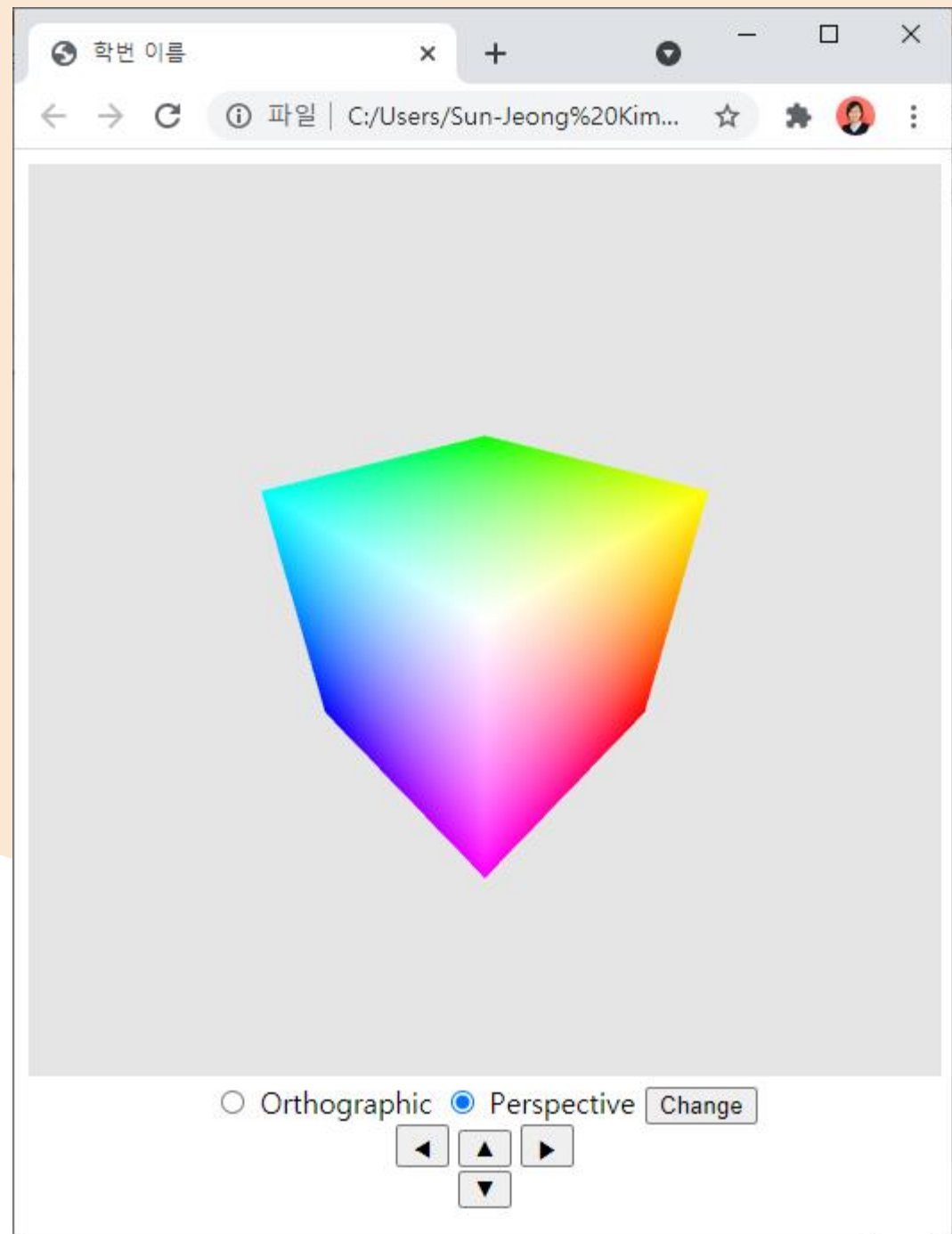
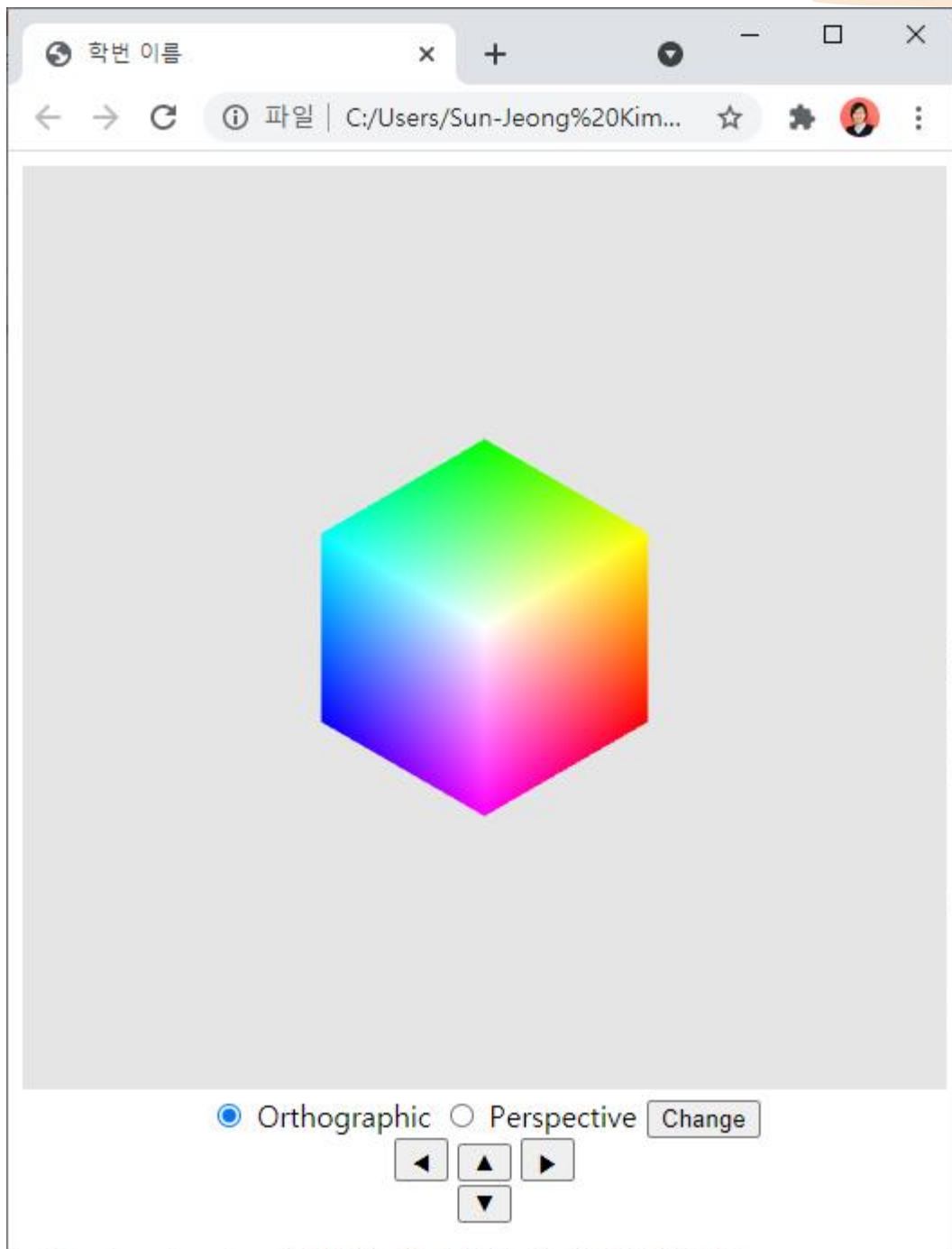


```
view.js - Visual Studio Code
File Edit Selection View Go Run Terminal Help
view.html JS view.js JS MV.js
C: > Users > Sun-Jeong Kim > Desktop > CG > JS view.js > [eye] eye
1  var gl;
2  var points = [];
3  var colors = [];
4
5  var modelViewMatrix, projectionMatrix;
6  var modelViewMatrixLoc, projectionMatrixLoc;
7  var eye = vec3(1.0, 1.0, 1.0);
8  var at = vec3(0.0, 0.0, 0.0);
9  var up = vec3(0.0, 1.0, 0.0);
10
11 var trballMatrix = mat4(1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1);
12
13 window.onload = function init()
14 {
15     var canvas = document.getElementById("gl-canvas");
16
17     gl = WebGLUtils.setupWebGL(canvas);
18     if( !gl ) {
19         alert("WebGL isn't available!");
20     }
21
22     generateColorCube();
23
24     // virtual trackball
```



연습 문제 (2)

- perspective() 함수에서 fovy 파라미터 값을 변경해보고, 그 의미를 파악하시오.
 - 예) 90도 대신 60도 또는 120도
- perspective() 함수에서 near, far 파라미터 값을 변경해보고, 그 의미를 파악하시오.
 - 0.1 대신 0.01 또는 1.0
 - 1000 대신 100 또는 10000



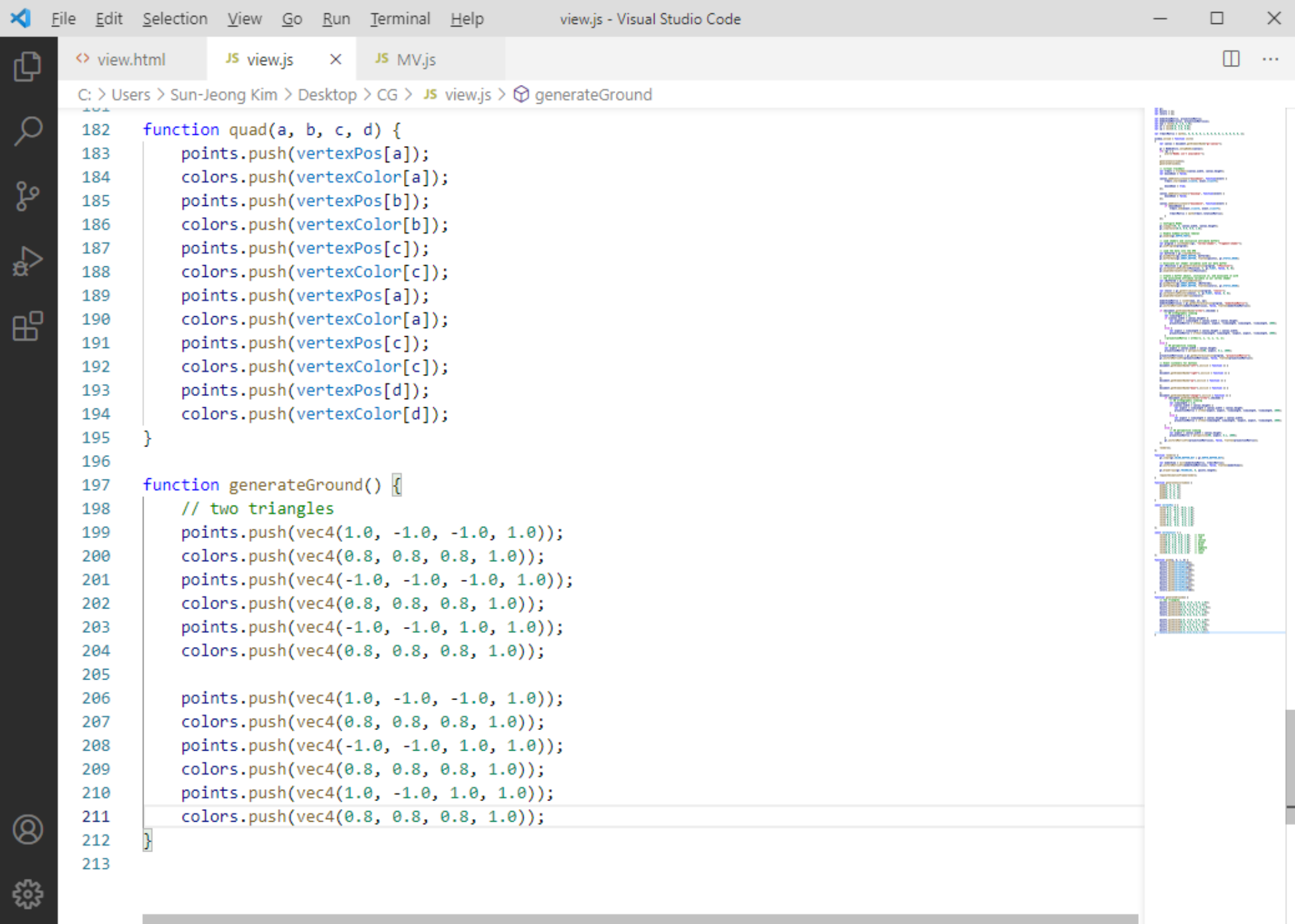
연습 문제 (3)

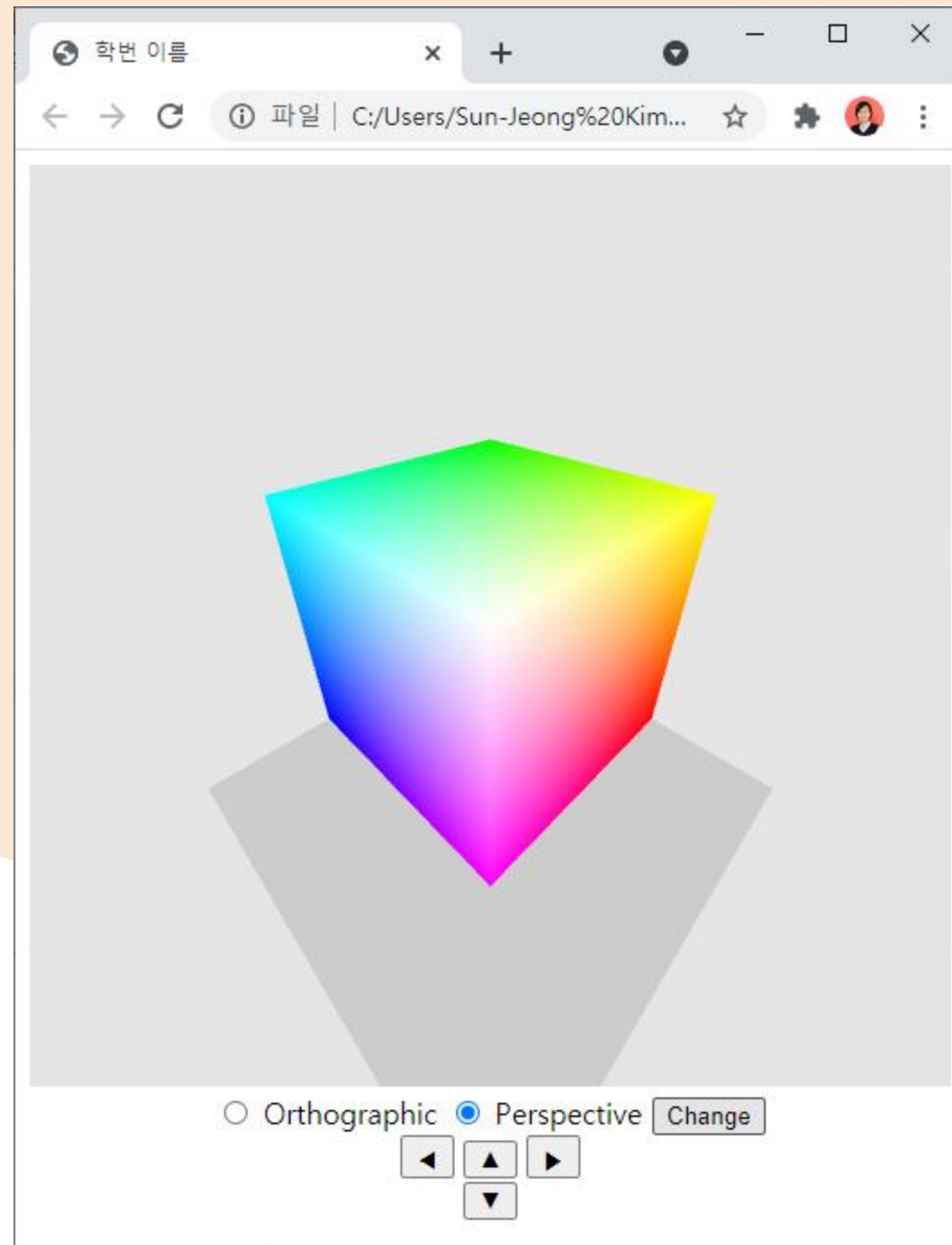
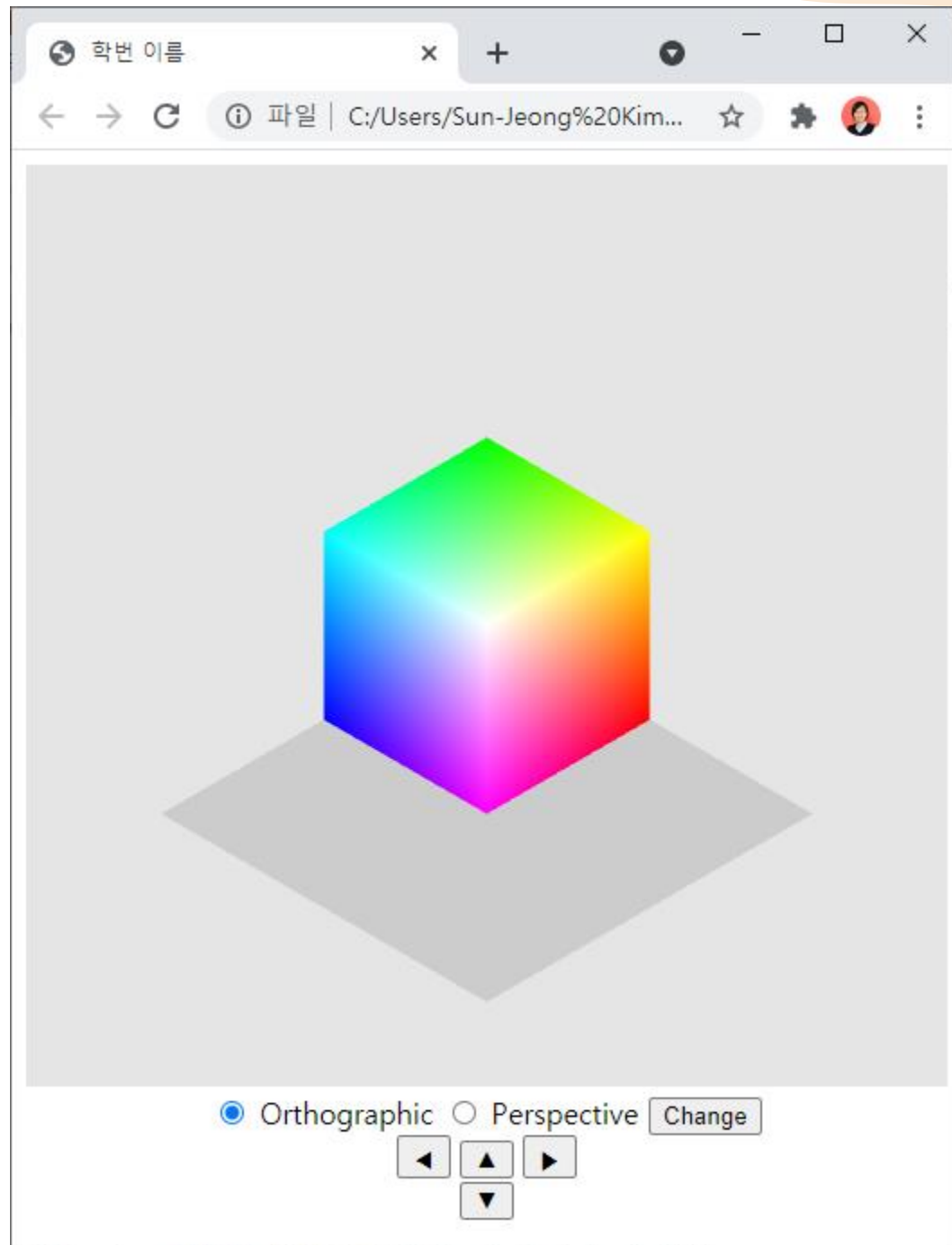
- 라디오 버튼을 만들어 Projection 방법을 선택할 수 있도록 구현하시오.
- Change 버튼을 누르면 선택된 Projection 방법으로 변경되도록 하시오.

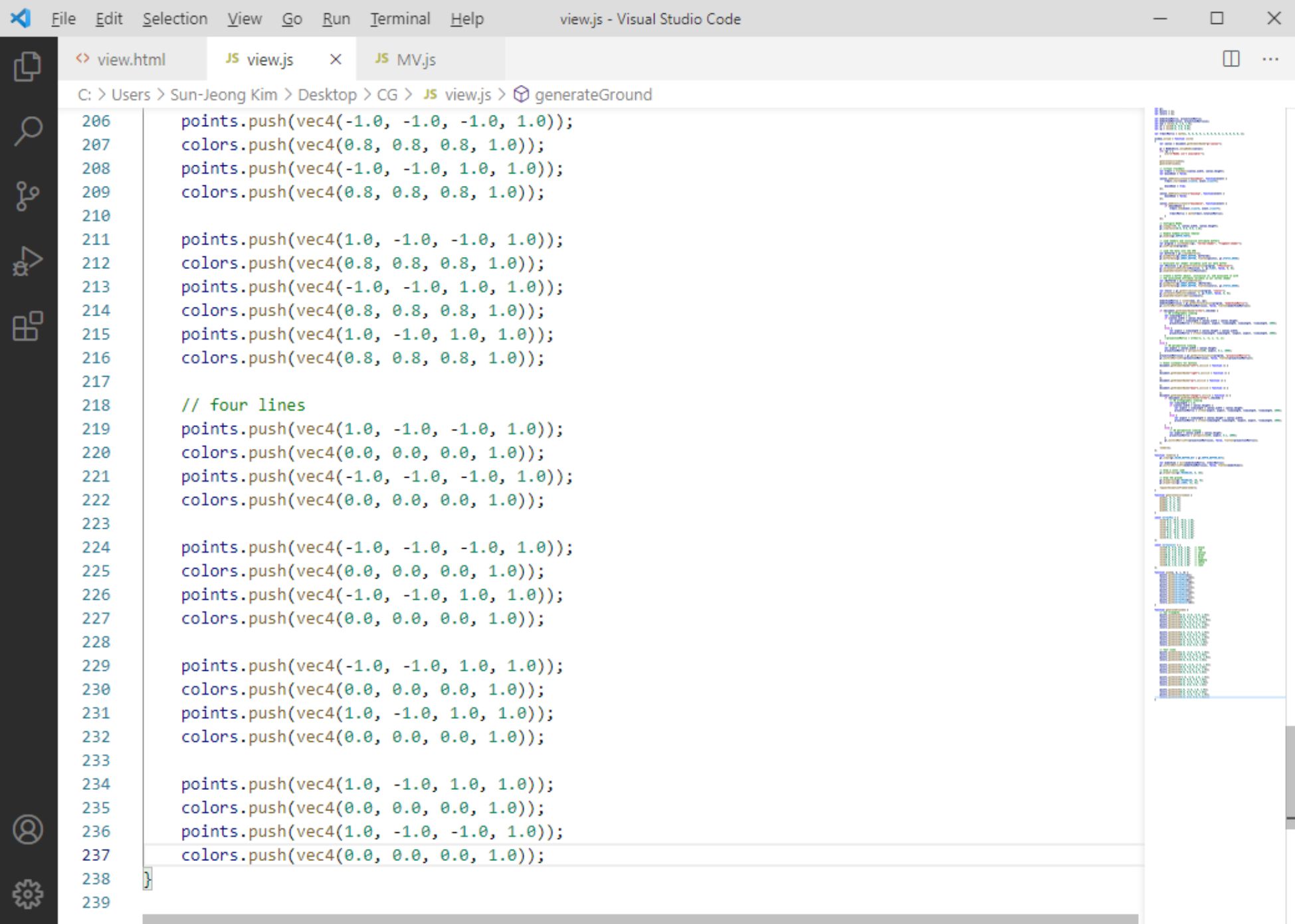
Drawing the Ground

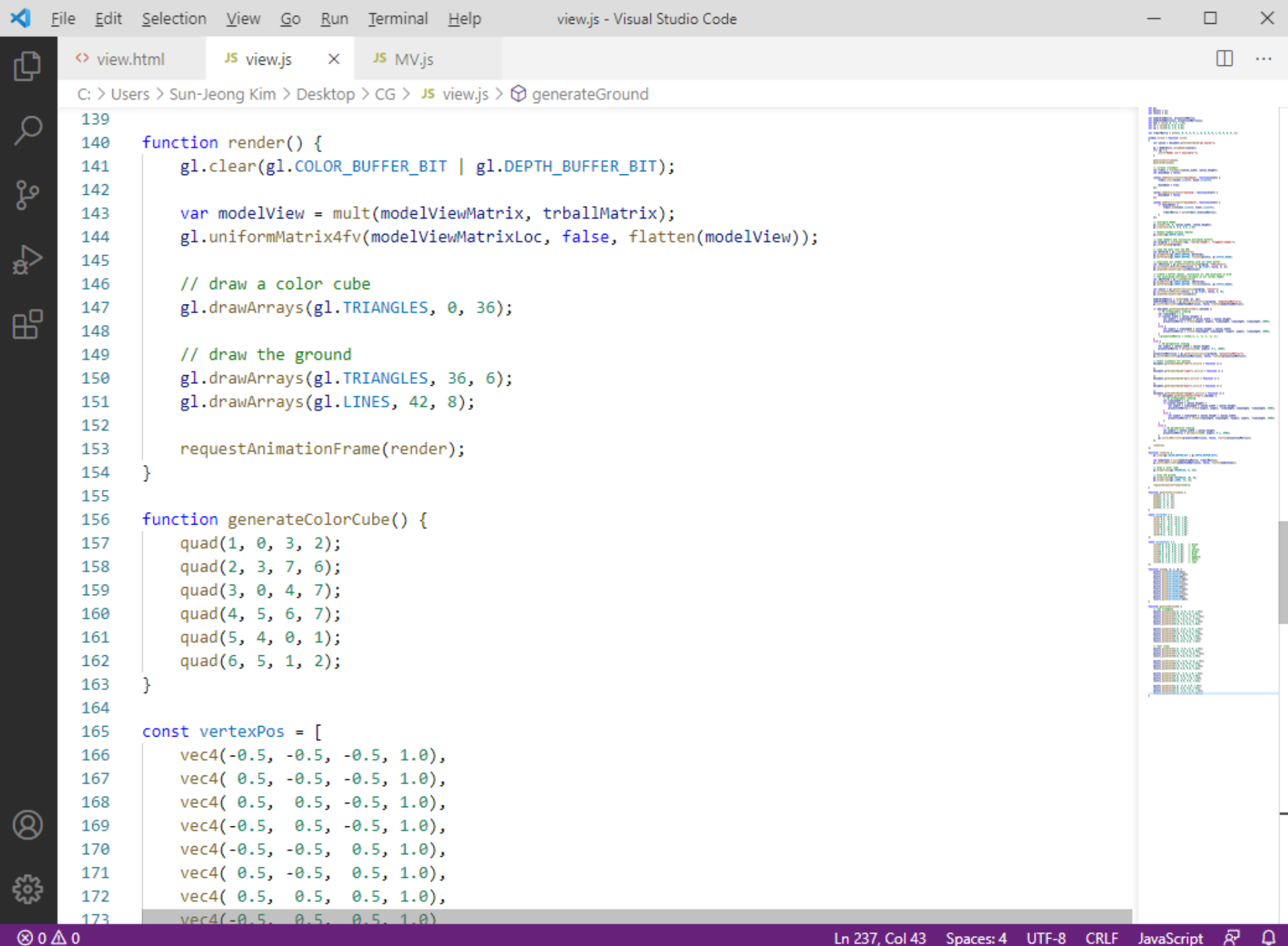


```
view.js - Visual Studio Code
view.html JS view.js JS MV.js
C: > Users > Sun-Jeong Kim > Desktop > CG > JS view.js > init
1  var gl;
2  var points = [];
3  var colors = [];
4
5  var modelViewMatrix, projectionMatrix;
6  var modelViewMatrixLoc, projectionMatrixLoc;
7  var eye = vec3(1.0, 1.0, 1.0);
8  var at = vec3(0.0, 0.0, 0.0);
9  var up = vec3(0.0, 1.0, 0.0);
10
11 var trballMatrix = mat4(1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1);
12
13 window.onload = function init()
14 {
15     var canvas = document.getElementById("gl-canvas");
16
17     gl = WebGLUtils.setupWebGL(canvas);
18     if( !gl ) {
19         alert("WebGL isn't available!");
20     }
21
22     generateColorCube();
23     generateGround();
24 }
```



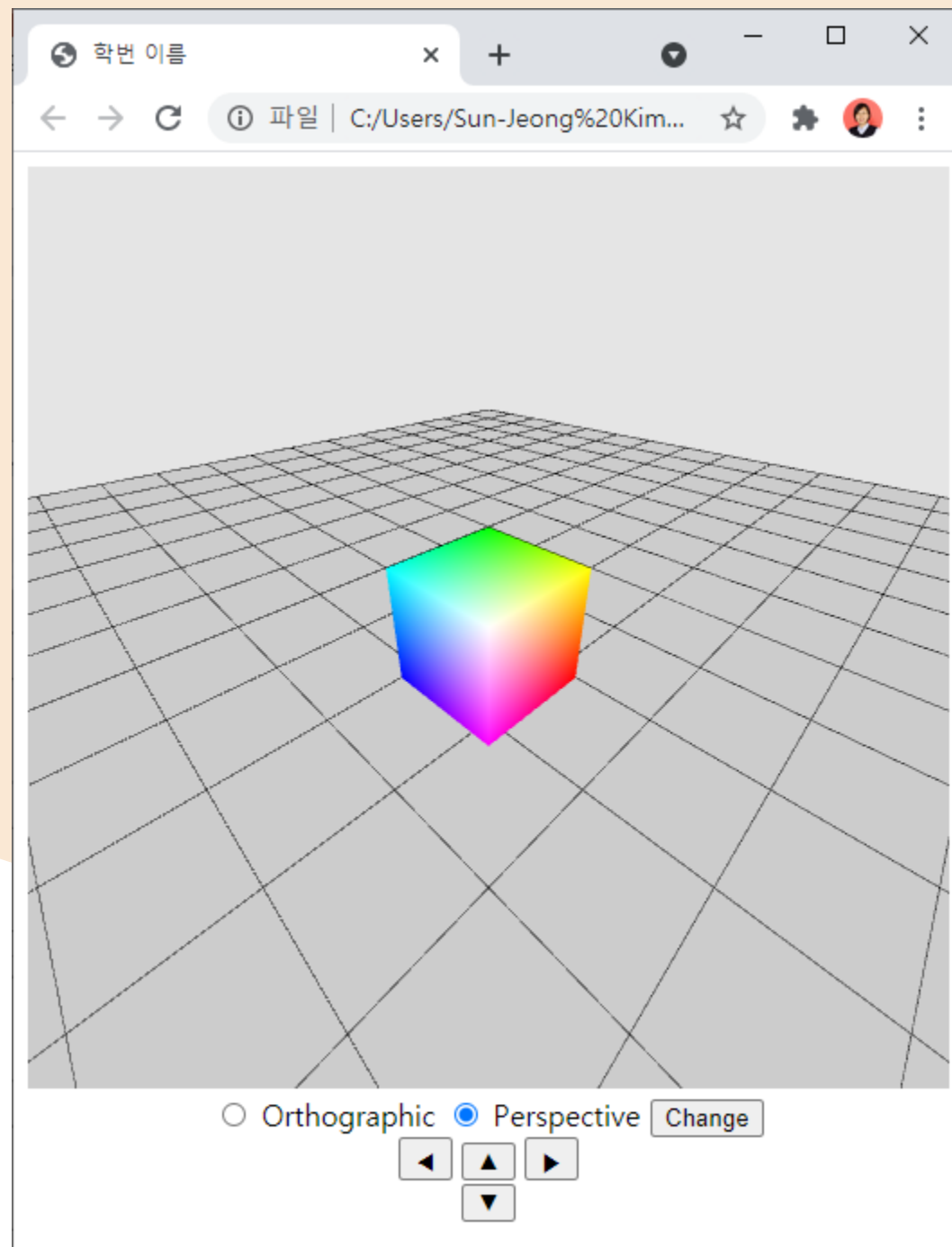
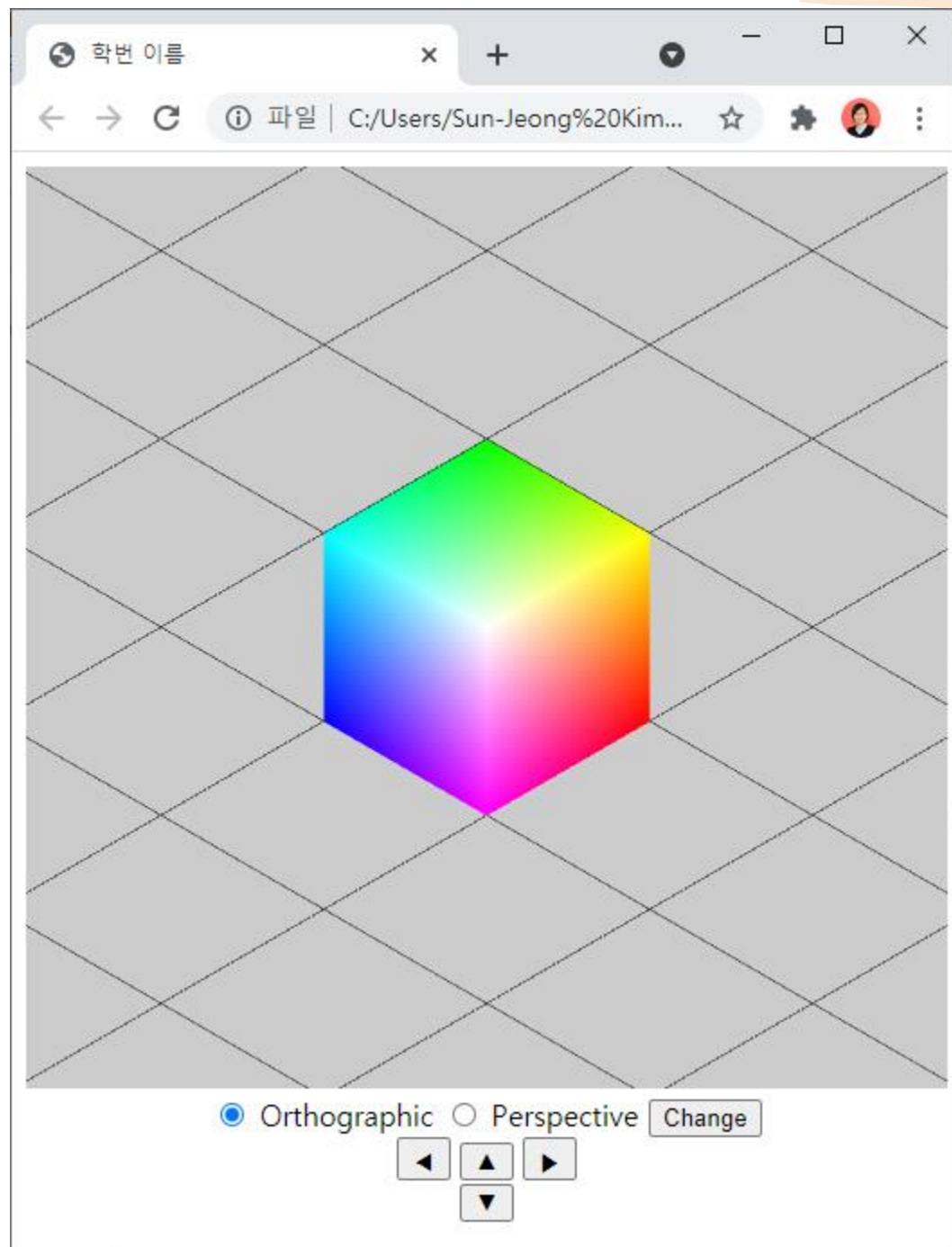


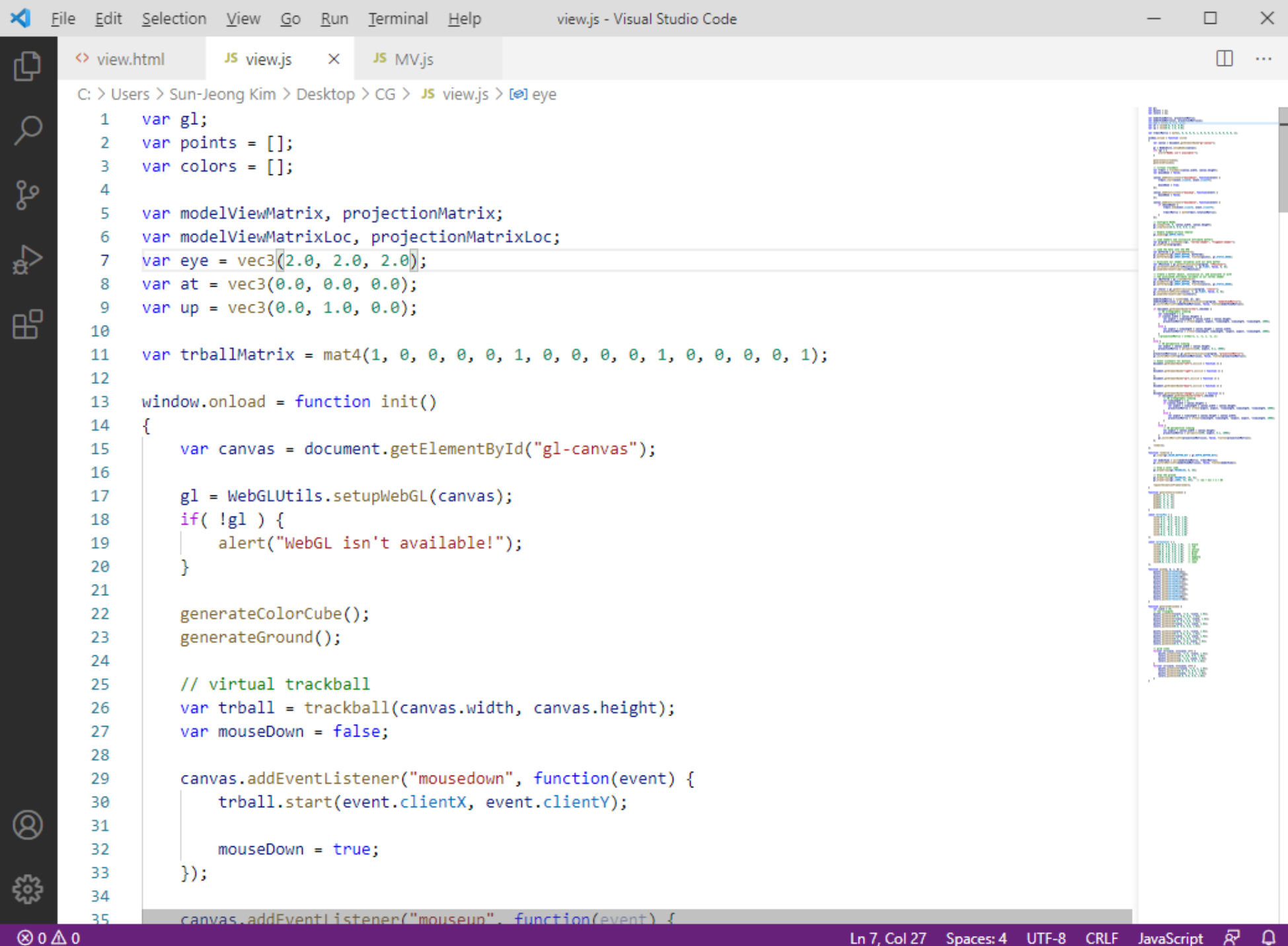




연습 문제 (4)

- Ground의 크기를 10배 늘리시오.
- Gound 간격 1마다 격자 선을 그리시오.
- 카메라의 위치를 (2, 2, 2)로 변경하시오.



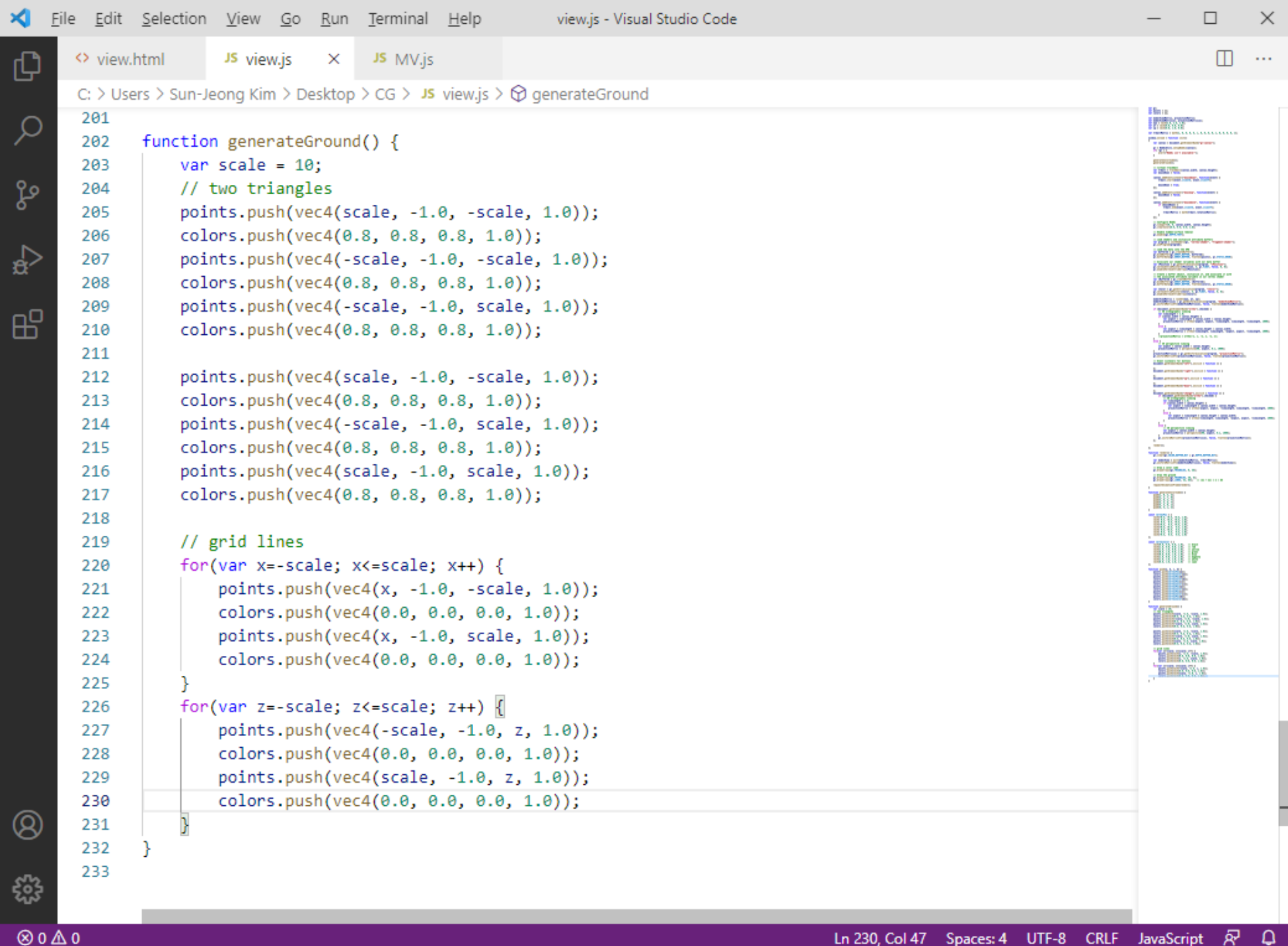


view.html JS view.js JS MV.js

C: > Users > Sun-Jeong Kim > Desktop > CG > JS view.js > render

```
139
140 function render() {
141     gl.clear(gl.COLOR_BUFFER_BIT | gl.DEPTH_BUFFER_BIT);
142
143     var modelView = mult(modelViewMatrix, trballMatrix);
144     gl.uniformMatrix4fv(modelViewMatrixLoc, false, flatten(modelView));
145
146     // draw a color cube
147     gl.drawArrays(gl.TRIANGLES, 0, 36);
148
149     // draw the ground
150     gl.drawArrays(gl.TRIANGLES, 36, 6);
151     gl.drawArrays(gl.LINES, 42, 84); // (21 + 21) * 2 = 84
152
153     requestAnimationFrame(render);
154 }
155
156 function generateColorCube() {
157     quad(1, 0, 3, 2);
158     quad(2, 3, 7, 6);
159     quad(3, 0, 4, 7);
160     quad(4, 5, 6, 7);
161     quad(5, 4, 0, 1);
162     quad(6, 5, 1, 2);
163 }
164
165 const vertexPos = [
166     vec4(-0.5, -0.5, -0.5, 1.0),
167     vec4( 0.5, -0.5, -0.5, 1.0),
168     vec4( 0.5,  0.5, -0.5, 1.0),
169     vec4(-0.5,  0.5, -0.5, 1.0),
170     vec4(-0.5, -0.5,  0.5, 1.0),
171     vec4( 0.5, -0.5,  0.5, 1.0),
172     vec4( 0.5,  0.5,  0.5, 1.0),
173     vec4(-0.5,  0.5,  0.5, 1.0)
```





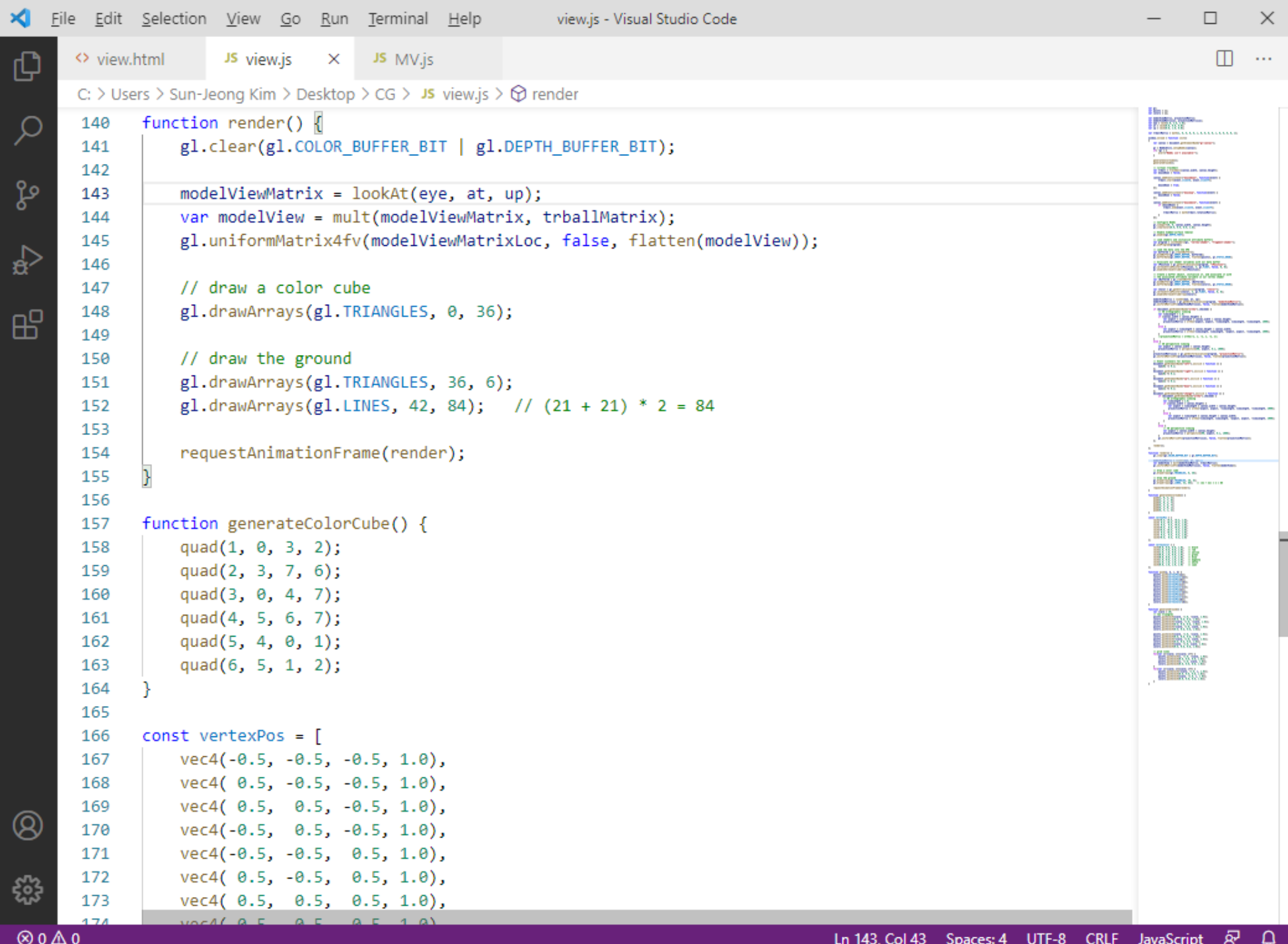
Walking Through

```

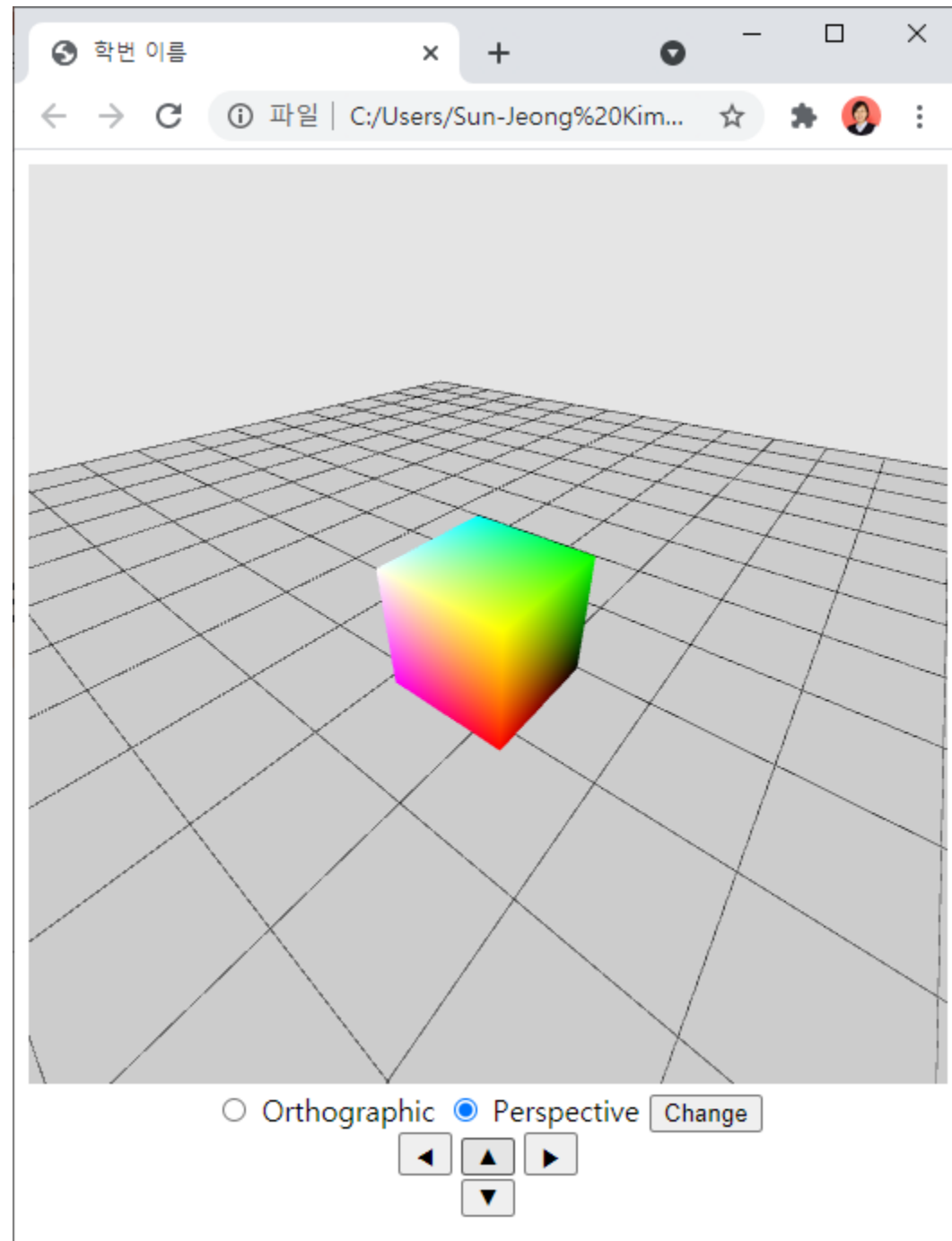
89     else {
90         var aspect = viewLength * canvas.height / canvas.width;
91         projectionMatrix = ortho(-viewLength, viewLength, -aspect, aspect, -viewLength, 1000);
92     }
93     //projectionMatrix = ortho(-1, 1, -1, 1, -1, 1);
94 }
95 else {
96     // 3D perspective viewing
97     var aspect = canvas.width / canvas.height;
98     projectionMatrix = perspective(90, aspect, 0.1, 1000);
99 }
100 projectionMatrixLoc = gl.getUniformLocation(program, "projectionMatrix");
101 gl.uniformMatrix4fv(projectionMatrixLoc, false, flatten(projectionMatrix));
102
103 // Event listeners for buttons
104 document.getElementById("left").onclick = function () {
105     eye[0] -= 0.1;
106 };
107 document.getElementById("right").onclick = function () {
108     eye[0] += 0.1;
109 };
110 document.getElementById("up").onclick = function () {
111     eye[2] -= 0.1;
112 };
113 document.getElementById("down").onclick = function () {
114     eye[2] += 0.1;
115 };

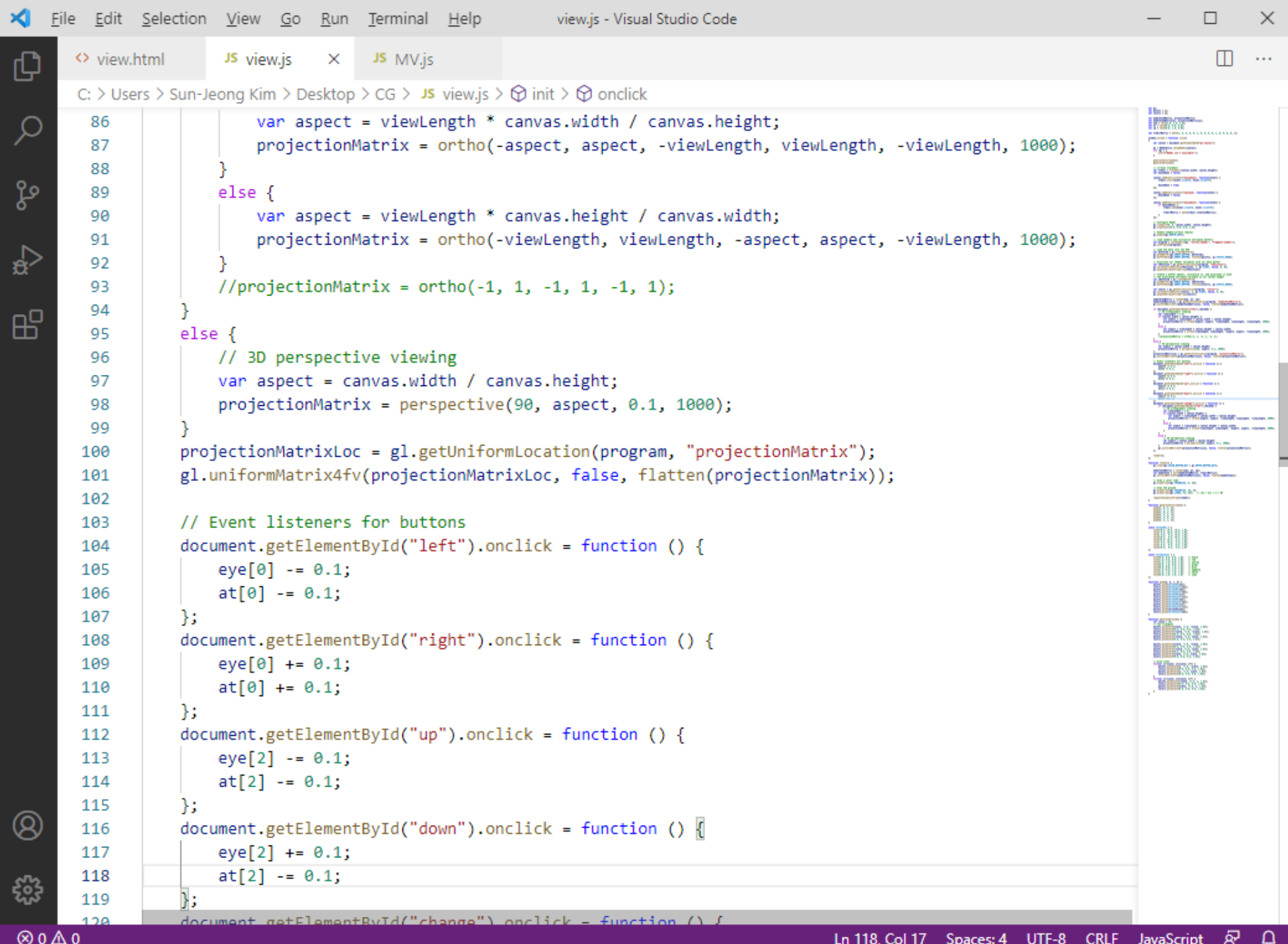
```

[illegible]

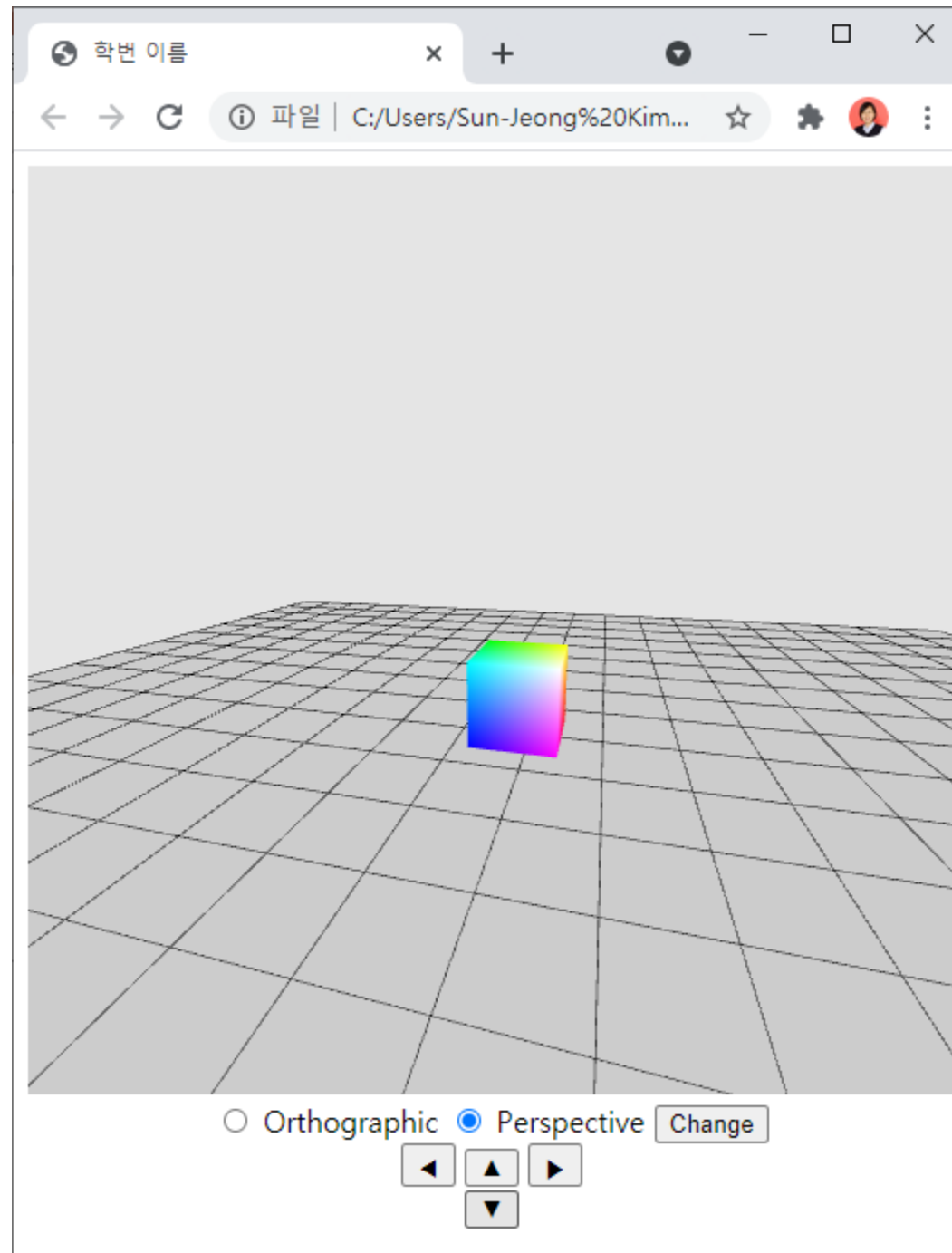


What's Wrong?





Is it Natural?



연습 문제 (5)

- ◀와 ▶ 버튼 입력에 대해,
 - 카메라의 로컬 y 축 회전하도록 구현하시오.
 - 즉, 제자리에서 바라보는 방향만 변경하시오.
- ▲와 ▼ 버튼 입력에 대해,
 - 카메라가 바라보는 방향으로 전진 또는 후진하도록 구현하시오.
- 카메라의 위치가 Ground 밖으로 나가지 못하도록 구현하시오.