# Lighting

10<sup>TH</sup> WEEK, 2021



### **Point Light Sources**

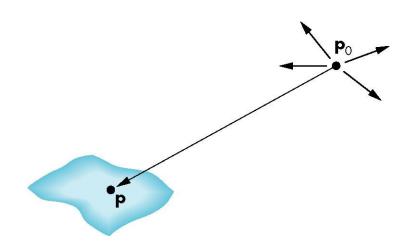
- Emitting light equally in all directions
  - $\mathbf{p}_0$ : the location of a point light source

$$\mathbf{I}(\mathbf{p}_0) = \begin{bmatrix} I_r(\mathbf{p}_0) \\ I_g(\mathbf{p}_0) \\ I_b(\mathbf{p}_0) \end{bmatrix}$$

- Attenuation
  - Proportional to the inverse square distance

$$\mathbf{I}(\mathbf{p}, \mathbf{p}_0) = \frac{1}{|\mathbf{p} - \mathbf{p}_0|^2} \mathbf{I}(\mathbf{p}_0)$$

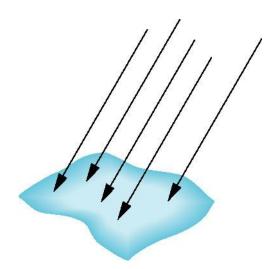
$$\mathbf{I}(\mathbf{p}, \mathbf{p}_0) = \frac{1}{k_c + k_l d + k_q d^2} \mathbf{I}(\mathbf{p}_0)$$



## **Directional Light Sources**

- Parallel direction of lights
  - Infinite distance away from the surface
  - Location → direction

$$\mathbf{p}_0 = \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} \qquad \mathbf{p}_0 = \begin{bmatrix} x \\ y \\ z \\ 0 \end{bmatrix}$$



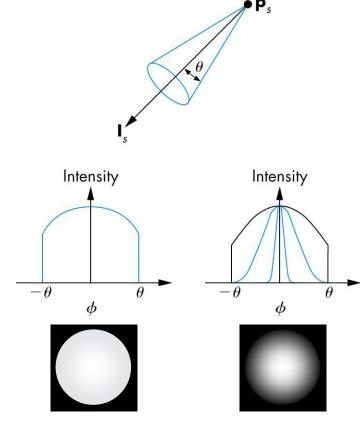
### **Spotlight Sources**

- Characterized by a narrow range of angle through which light is emitted
  - **p**<sub>s</sub>: apex of a cone
    - I<sub>s</sub>: direction of pointing
    - $\theta$ : angle to determine width
- Distribution of light
  - Concentrating in the center

$$\cos \phi = \mathbf{s} \cdot \mathbf{l}_{s}$$

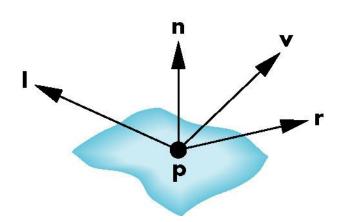
• Light intensity drop off

$$\cos^e \phi = (\mathbf{s} \cdot \mathbf{l}_s)^e$$



### **Phong Reflection Model**

- A simple model that can compute rapidly
- Three components (light-material interactions)
  - Ambient
  - <u>Diffuse</u>
  - <u>Specular</u>
- Using four vectors
  - **n**: <u>normal</u>
  - v: to the <u>viewer</u> or COP
  - 1: to <u>light</u> source
  - **r**: perfect <u>reflector</u>



#### **Ambient Reflection**

- Same at every point on the surface
- Ambient reflection coefficient

$$\mathbf{k}_{a} = (k_{ar}, k_{ag}, k_{ab}), \quad 0 \le k_{ar}, k_{ag}, k_{ab} \le 1$$

- Amount reflected
  - Some is absorbed and some is reflected
- Three components (red, green, blue)
- Ambient reflection term in rendering equation

$$\mathbf{I}_a = \mathbf{k}_a \mathbf{L}_a$$

- Can be any of the individual light sources
- Can be a <u>global</u> ambient term

#### **Diffuse** Reflection

- Light scattered equally in all directions
  - Perfectly diffuse surface
  - → So rough that there is no preferred angle of reflection
- <u>Lambert</u>'s law
  - Amount of light reflected is proportional to vertical component of incoming light
    - Reflected light  $\propto \cos u$

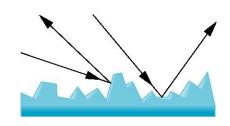
$$\cos u = \mathbf{l} \cdot \mathbf{n}$$

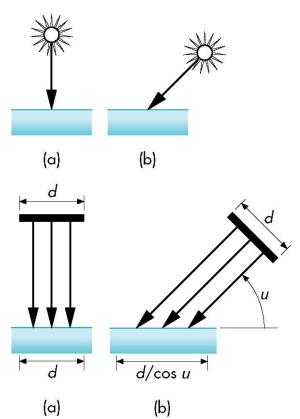
• Diffuse reflection term

$$\mathbf{I}_d = \mathbf{k}_d (\mathbf{l} \cdot \mathbf{n}) \mathbf{L}_d$$

• Incorporating a <u>distance</u> term

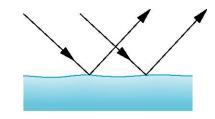
$$\mathbf{I}_{d} = \frac{\mathbf{k}_{d}}{k_{c} + k_{l}d + k_{a}d^{2}} (\mathbf{l} \cdot \mathbf{n}) \mathbf{L}_{d}$$





### **Specular Reflection**

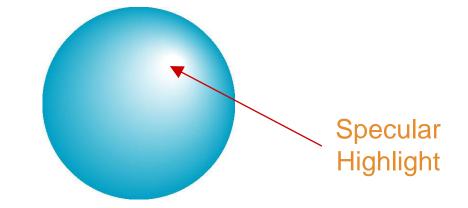
Smooth surfaces show specular highlights

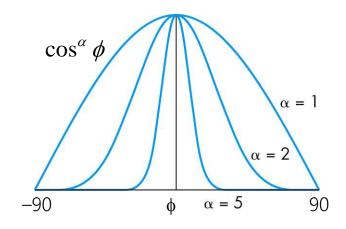


Specular reflection term

$$\mathbf{I}_s = \mathbf{k}_s (\mathbf{r} \cdot \mathbf{v})^{\alpha} \mathbf{L}_s$$

- α: <u>shininess</u> coefficient
  - $\alpha \rightarrow$  infinite : mirror
  - $100 < \alpha < 200$ : metal
  - $5 < \alpha < 10$ : plastic





### **Drawing** a Color Cube

```
Edit Selection View Go Run Terminal Help
                                                                  light.html - Visual Studio Code
◇ light.html ×
                JS light.js
C: > Users > Sun-Jeong Kim > Desktop > CG > ♦ light.html > ♦ html > ♦ head > ♦ title
       <!DOCTYPE html>
       <html>
            <head>
               <title>학번 이름</title>
  4
                                                                                                                                                   THE REAL PROPERTY.
               <script id="vertex-shader" type="x-shader/x-vertex">
               attribute vec4 vPosition;
               attribute vec4 vColor;
               varying vec4 fColor;
  8
 10
               void main() {
                    gl_Position = vPosition;
 11
                    fColor = vColor;
 12
 13
               </script>
 14
 15
               <script id="fragment-shader" type="x-shader/x-fragment">
 16
               precision mediump float;
 17
               varying vec4 fColor;
 18
 19
 20
               void main() {
                    gl_FragColor = fColor;
 22
                </script>
 23
 24
```

```
light.html - Visual Studio Code
   <u>File Edit Selection View Go Run Terminal Help</u>
                                                                                                                                                             П ...
      ◇ light.html ×
                      JS light.js
      C: > Users > Sun-Jeong Kim > Desktop > CG > ↔ light.html > ↔ html > ↔ head > ↔ title
                                                                                                                                                      BOOM
        15
        16
                      <script id="fragment-shader" type="x-shader/x-fragment">
                                                                                                                                                       COLUMN TWO
                      precision mediump float;
        17
مع
                                                                                                                                                        COLUMN ...
                      varying vec4 fColor;
        18
                                                                                                                                                       19
        20
                      void main() {
                          gl_FragColor = fColor;
        21
        22
        23
                      </script>
œ
        24
        25
                      <script type="text/javascript" src="Common/webgl-utils.js"></script>
                      <script type="text/javascript" src="Common/initShaders.js"></script>
        26
        27
                      <script type="text/javascript" src="Common/MV.js"></script>
                      <script type="text/javascript" src="trackball.js"></script>
        28
                      <script type="text/javascript" src="light.js"></script>
        29
                  </head>
        30
                  <body>
        31
                      <canvas id="gl-canvas" width="512" height="512">
        32
                          Oops... your browser doesn't support the HTML5 canvas element!
        33
                      </canvas>
        34
                      <div style="width: 512px; text-align: center;">
        35
                          <button id="xButton">Rotate X</button>
        36
                          <button id="yButton">Rotate Y</button>
        37
                          <button id="zButton">Rotate Z</button>
        38
        39
                          <button id="buttonT">Toggle Rotate/button>
                      </div>
        40
                  </body>
        41
              </html>
        42
(8)
ξ<sup>6</sup>2
```

<u>File Edit Selection View Go Run Terminal Help</u> light.js - Visual Studio Code ... light.html JS light.js  $\times$ C: > Users > Sun-Jeong Kim > Desktop > CG > JS light.js > ♦ render var gl; var points = []; Commence of the last of the la var colors = []; FREE PROPERTY. مع Marian San San San Name and Address of the Owner, where var axis = 0; var theta = [0, 0, 0];THE PERSON var rotation = false; PROPERTY OF STREET 8 The second AND DESCRIPTION OF THE var modelViewMatrix, projectionMatrix; WE STORY OF THE PARTY OF 留 var modelViewMatrixLoc, projectionMatrixLoc; 10 Assessment appropriate the second DECRYPHANCE OF .... const eye = vec3(0.0, 0.0, 1.0); 11 THE RESERVE OF THE PERSON. const at = vec3(0.0, 0.0, 0.0); 12 const up = vec3(0.0, 1.0, 0.0); 13 14 15 var trballMatrix = mat4(1, 0, 0, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1); var numVertCubeTri; 16 17 window.onload = function init() 18 19 var canvas = document.getElementById("gl-canvas"); 20 21 22 gl = WebGLUtils.setupWebGL(canvas); if( !gl ) { 23 alert("WebGL isn't available!"); 24 25 26 generateColorCube(); 27 28 // virtual trackball 29 var trball = trackball(canvas.width, canvas.height); 30 31 var mouseDown = false; 32 canvas.addEventListener("mousedown", function (event) { 33 trball.start(event.clientX, event.clientY); 34 ⊗ 0 ∆ 0

```
<u>File Edit Selection View Go Run Terminal Help</u>
                                                                                                                                                                                         light.js - Visual Studio Code
                                                                                                                                                                                                                                                                                                                                                                                                               □ ...
                 light.html
                                                          JS light.js
                                                                                       ×
                 C: > Users > Sun-Jeong Kim > Desktop > CG > JS light.js > ♥ render
                                                         mouseDown = true;
                      36
                                                                                                                                                                                                                                                                                                                                                                                              Commence of the last of the la
                      37
                                              });
                      38
                                                                                                                                                                                                                                                                                                                                                                                                THE PERSON NAMED IN
 مع
                                                                                                                                                                                                                                                                                                                                                                                                The second line to the second
                                               canvas.addEventListener("mouseup", function (event) {
                      39
                                                         mouseDown = false;
                      40
                                              });
                      41
                                                                                                                                                                                                                                                                                                                                                                                               Parameter ...
                      42
                                                                                                                                                                                                                                                                                                                                                                                                MINISTER ...
                                                                                                                                                                                                                                                                                                                                                                                                THE PERSON NAMED IN
                                               canvas.addEventListener("mousemove", function (event) {
                      43
                                                                                                                                                                                                                                                                                                                                                                                                Contract Property
                                                         if (mouseDown) {
                      44
                                                                                                                                                                                                                                                                                                                                                                                                PRESIDENT AND ADDRESS.
留
                                                                                                                                                                                                                                                                                                                                                                                                WEST
                                                                    trball.end(event.clientX, event.clientY);
                      45
                                                                                                                                                                                                                                                                                                                                                                                                 ARREST SERVICES SERVICES
                                                                                                                                                                                                                                                                                                                                                                                                DECEMBEL OF SEC. ...
                      46
                                                                                                                                                                                                                                                                                                                                                                                               THE PERSON NAMED IN
                                                                    trballMatrix = mat4(trball.rotationMatrix);
                      47
                      48
                                              });
                      49
                                                                                                                                                                                                                                                                                                                                                                                              50
                                                                                                                                                                                                                                                                                                                                                                                              // Configure WebGL
                      51
                                              gl.viewport(0, 0, canvas.width, canvas.height);
                      52
                                               gl.clearColor(1.0, 1.0, 1.0, 1.0);
                      53
                      54
                                              // Enable hidden-surface removal
                     55
                                              gl.enable(gl.DEPTH TEST);
                      56
                      57
                                              // Load shaders and initialize attribute buffers
                      58
                                              var program = initShaders(gl, "vertex-shader", "fragment-shader");
                      59
                                              gl.useProgram(program);
                      60
                      61
                                              // Load the data into the GPU
                      62
                                              var bufferId = gl.createBuffer();
                      63
                                              gl.bindBuffer(gl.ARRAY_BUFFER, bufferId);
                      64
                                              gl.bufferData(gl.ARRAY_BUFFER, flatten(points), gl.STATIC_DRAW);
                      65
(8)
                      66
                                              // Associate our shader variables with our data buffer
                      67
                                              var vPosition = gl.getAttribLocation(program, "vPosition");
                      68
                                              gl.vertexAttribPointer(vPosition, 4, gl.FLOAT, false, 0, 0);
⊗ 0 ∆ 0
                                                                                                                                                                                                                                                                                                       Ln 126, Col 51 Spaces: 4 UTF-8 CRLF JavaScript 🛱 🚨
```

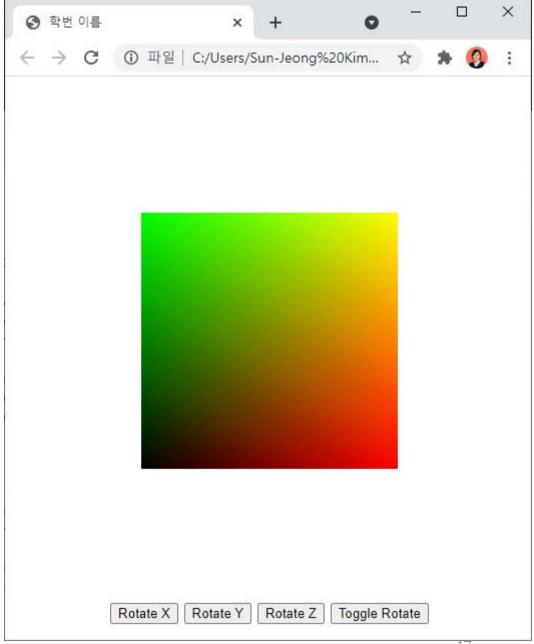
```
light.js - Visual Studio Code
       File Edit Selection View Go Run Terminal Help
                                                                                                                                                                                                                                                                                                                                                                П ...
               light.html
                                                    JS light.js
                                                                            \times
               C: > Users > Sun-Jeong Kim > Desktop > CG > JS light.js > ♦ render
                                         gl.enableVertexAttribArray(vPosition);
                  71
                                                                                                                                                                                                                                                                                                                                                 Company of the last
                                        // Create a buffer object, initialize it, and associate it with
                   72
                                                                                                                                                                                                                                                                                                                                                  FIRE PROPERTY AND ADDRESS.
مع
                   73
                                        // the associated attribute variable in our vertex shader
                                        var cBufferId = gl.createBuffer();
                   74
                                        gl.bindBuffer(gl.ARRAY BUFFER, cBufferId);
                   75
                                                                                                                                                                                                                                                                                                                                                  AND DESCRIPTION OF THE PARTY.
                                         gl.bufferData(gl.ARRAY_BUFFER, flatten(colors), gl.STATIC_DRAW);
                   76
                                                                                                                                                                                                                                                                                                                                                  MAN DE TON
                   77
                                                                                                                                                                                                                                                                                                                                                  STATE OF THE REAL PROPERTY.
                   78
                                         var vColor = gl.getAttribLocation(program, "vColor");
留
                                                                                                                                                                                                                                                                                                                                                  SERVICE OF SERVICE
                                                                                                                                                                                                                                                                                                                                                  WE Serve was ---
                                         gl.vertexAttribPointer(vColor, 4, gl.FLOAT, false, 0, 0);
                   79
                                                                                                                                                                                                                                                                                                                                                   ARREST STATE OF THE REAL PROPERTY.
                                                                                                                                                                                                                                                                                                                                                  SECRETARIAN DE ....
                                         gl.enableVertexAttribArray(vColor);
                   80
                                                                                                                                                                                                                                                                                                                                                 THE PERSON NAMED IN COLUMN 2 IS NOT THE OWNER.
                                                                                                                                                                                                                                                                                                                                                  Same and the same 
                   81
                                         modelViewMatrix = lookAt(eye, at, up);
                   82
                                         modelViewMatrixLoc = gl.getUniformLocation(program, "modelViewMatrix");
                   83
                                         gl.uniformMatrix4fv(modelViewMatrixLoc, false, flatten(modelViewMatrix));
                   84
                                                                                                                                                                                                                                                                                                                                                 85
                   86
                                         // 3D orthographic viewing
                                         var viewLength = 1.0;
                   87
                                        if (canvas.width > canvas.height) {
                   88
                   89
                                                  var aspect = viewLength * canvas.width / canvas.height;
                                                  projectionMatrix = ortho(-aspect, aspect, -viewLength, viewLength, -viewLength, 1000);
                   90
                   91
                   92
                                         else {
                                                  var aspect = viewLength * canvas.height / canvas.width;
                   93
                   94
                                                  projectionMatrix = ortho(-viewLength, viewLength, -aspect, aspect, -viewLength, 1000);
                   95
                   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 huttons
⊗ 0 ∆ 0
```

```
<u>File Edit Selection View Go Run Terminal Help</u>
                                                                                                                                                                                                                                                                                                                                                                                                                                                                      light.js - Visual Studio Code
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      □ ...
                                          light.html
                                                                                                                                              JS light.js
                                                                                                                                                                                                               \times
                                          C: > Users > Sun-Jeong Kim > Desktop > CG > JS light.js > ♦ render
                                                                                                                 // Event listeners for buttons
                                             104
                                                                                                                  document.getElementById("xButton").onclick = function () {
                                              105
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              Contract of the last
                                              106
                                                                                                                                            axis = 0;
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               FREE PROPERTY.
 مع
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 THE RESERVE THE TAXABLE
                                              107
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  Name and Address of the Owner, where
                                                                                                                  document.getElementById("yButton").onclick = function () {
                                              108
                                                                                                                                            axis = 1;
                                              109
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               National contraction of the Cont
                                             110
                                                                                                                   };
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 2007216 mm.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  March Street, 
                                                                                                                  document.getElementById("zButton").onclick = function () {
                                             111
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               AND DESCRIPTION OF THE
                                            112
                                                                                                                                            axis = 2;
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               THE RESIDENCE AND ADDRESS.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 WEST THE REST
                                            113
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   ARREST SERVICES SERVICES
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 DECEMBEL OF SEC. ...
                                                                                                                  document.getElementById("buttonT").onclick = function () {
                                             114
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               THE PERSON NAMED IN
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  Statement of the statem
                                             115
                                                                                                                                            rotation = !rotation;
                                            116
                                                                                                                 };
                                             117
                                                                                                                 render();
                                             118
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             119
                                             120
                                                                                        function render() {
                                             121
                                            122
                                                                                                                  gl.clear(gl.COLOR_BUFFER_BIT | gl.DEPTH_BUFFER_BIT);
                                            123
                                                                                                                 if( rotation ) theta[axis] += 2.0;
                                             124
                                             125
                                                                                                                   gl.drawArrays(gl.TRIANGLES, 0, points.length);
                                              126
                                            127
                                                                                                                  window.requestAnimationFrame(render);
                                             128
                                             129
                                              130
                                                                                        function generateColorCube() {
                                             131
                                                                                                                  numVertCubeTri = 0;
                                             132
                                                                                                                quad(1, 0, 3, 2);
                                              133
(2)
                                              134
                                                                                                                quad(2, 3, 7, 6);
                                                                                                                quad(3, 0, 4, 7);
                                             135
                                              136
                                                                                                                quad(4, 5, 6, 7);
                                             137
                                                                                                                  quad(5, 4, 0, 1);
⊗ 0 ∆ 0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       Ln 126, Col 51 Spaces: 4 UTF-8 CRLF JavaScript 🔊 🚨
```

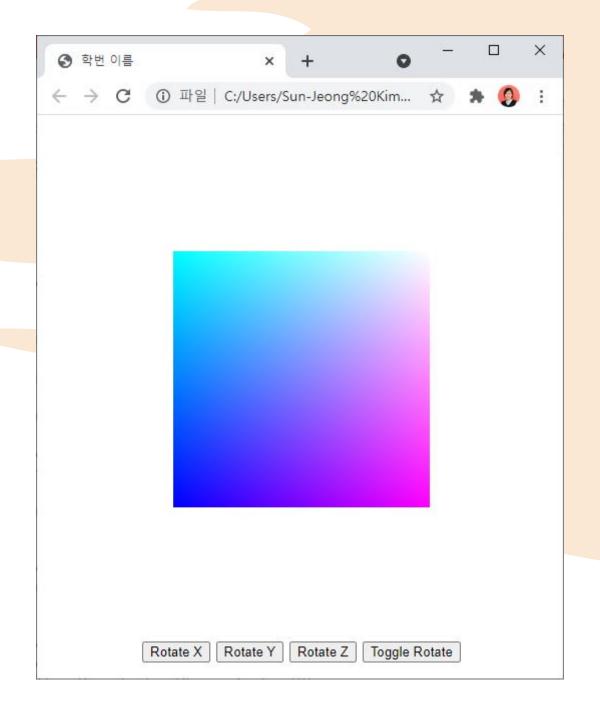
```
<u>File Edit Selection View Go Run Terminal Help</u>
                                                                                                                                                                                                                                                                                                                                                                                                      light.js - Visual Studio Code
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           □ ...
                                    light.html
                                                                                                                           JS light.js
                                                                                                                                                                                        ×
                                    C: > Users > Sun-Jeong Kim > Desktop > CG > JS light.js > ♦ render
                                                                                                  quad(6, 5, 1, 2);
                                        138
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       Billian
                                        139
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      Party or many
                                        140
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          FREE PROPERTY.
 مع
                                        141
                                                                            function quad(a, b, c, d) {
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           Marian San San San
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           The same of the sa
                                                                                                  vertexPos = [
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          Telephone and the second
                                        142
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          STATE OF STREET
                                                                                                                        vec4(-0.5, -0.5, -0.5, 1.0),
                                        143
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         Supplied of the Party of the Pa
                                        144
                                                                                                                       vec4( 0.5, -0.5, -0.5, 1.0),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           MOVEMENT ....
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           THE LOCAL PROPERTY.
                                                                                                                       vec4( 0.5, 0.5, -0.5, 1.0),
                                        145
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          THE RESERVED
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          Control of the last of
                                                                                                                       vec4(-0.5, 0.5, -0.5, 1.0),
                                        146
œ
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          PRESIDENCE AND ADDRESS.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           WE SHOW THE TAX TO SEE
                                                                                                                      vec4(-0.5, -0.5, 0.5, 1.0),
                                        147
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            Assessment appropriate the second
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          DECRYPHANCE OF ....
                                        148
                                                                                                                      vec4( 0.5, -0.5, 0.5, 1.0),
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         THE RESERVE OF THE PERSON.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          the state of the s
                                                                                                                       vec4( 0.5, 0.5, 0.5, 1.0),
                                        149
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          Total Contract
                                                                                                                        vec4(-0.5, 0.5, 0.5, 1.0)
                                        150
                                        151
                                                                                                  ];
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        152
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        vertexColor = [
                                        153
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       154
                                                                                                                        vec4(0.0, 0.0, 0.0, 1.0), // black
                                        155
                                                                                                                       vec4(1.0, 0.0, 0.0, 1.0), // red
                                        156
                                                                                                                       vec4(1.0, 1.0, 0.0, 1.0), // yellow
                                        157
                                                                                                                       vec4(0.0, 1.0, 0.0, 1.0), // green
                                        158
                                                                                                                       vec4(0.0, 0.0, 1.0, 1.0),
                                                                                                                                                                                                                                                                               // blue
                                                                                                                       vec4(1.0, 0.0, 1.0, 1.0),
                                                                                                                                                                                                                                                                                 // magenta
                                        159
                                                                                                                       vec4(1.0, 1.0, 1.0, 1.0), // white
                                        160
                                        161
                                                                                                                       vec4(0.0, 1.0, 1.0, 1.0)
                                                                                                                                                                                                                                                                                     // cyan
                                        162
                                                                                                  ];
                                        163
                                                                                                  // two triangles: (a, b, c) and (a, c, d)
                                        164
                                                                                                  points.push(vertexPos[a]);
                                        165
                                                                                                   colors.push(vertexColor[a]);
                                        166
                                                                                                  numVertCubeTri++;
                                        167
(2)
                                        168
                                                                                                  points.push(vertexPos[b]);
                                                                                                  colors.push(vertexColor[b]);
                                        169
                                                                                                  numVertCubeTri++;
                                        170
ξ<mark>6</mark>
                                       171
                                                                                                  points.push(vertexPos[c]);
                                                                                                    colors nush(vertexColor[cl):
 ⊗ 0 ∆ 0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                Ln 126, Col 51 Spaces: 4 UTF-8 CRLF JavaScript 🔊 🚨
```

Edit Selection View Go Run Terminal Help light.js - Visual Studio Code □ ... light.html JS light.js × C: > Users > Sun-Jeong Kim > Desktop > CG > JS light.js > ♦ render vertexColor = [ Billian 153 vec4(0.0, 0.0, 0.0, 1.0), // black 154 Commence of the last of the la vec4(1.0, 0.0, 0.0, 1.0), // red 155 FREE PROPERTY. مع 156 vec4(1.0, 1.0, 0.0, 1.0), // yellow Marian San San San Total St. vec4(0.0, 1.0, 0.0, 1.0), // green William or other 157 Santanan and American vec4(0.0, 0.0, 1.0, 1.0), // blue 158 159 vec4(1.0, 0.0, 1.0, 1.0), // magenta MOVEM .... THE LOCAL PROPERTY. vec4(1.0, 1.0, 1.0, 1.0), // white 160 THE RESIDENCE OF THE PERSON OF Control of the last of vec4(0.0, 1.0, 1.0, 1.0) // cyan 161 œ PRESIDENCE AND ADDRESS. WE Service was ---162 1; Assessment appropriate the second DECRYPHANCE OF .... 163 THE RESERVE OF THE PERSON. // two triangles: (a, b, c) and (a, c, d) 164 THE PERSON NAMED IN COLUMN TWO IS NOT THE OWNER. points.push(vertexPos[a]); 165 166 colors.push(vertexColor[a]); numVertCubeTri++; 167 168 points.push(vertexPos[b]); colors.push(vertexColor[b]); 169 170 numVertCubeTri++; points.push(vertexPos[c]); 171 172 colors.push(vertexColor[c]); numVertCubeTri++; 173 174 175 points.push(vertexPos[a]); colors.push(vertexColor[a]); 176 177 numVertCubeTri++; points.push(vertexPos[c]); 178 colors.push(vertexColor[c]); 179 numVertCubeTri++; 180 points.push(vertexPos[d]); 181 182 colors.push(vertexColor[d]); **(2)** 183 numVertCubeTri++; 184 185 ξ**ί** 

# What's Wrong?

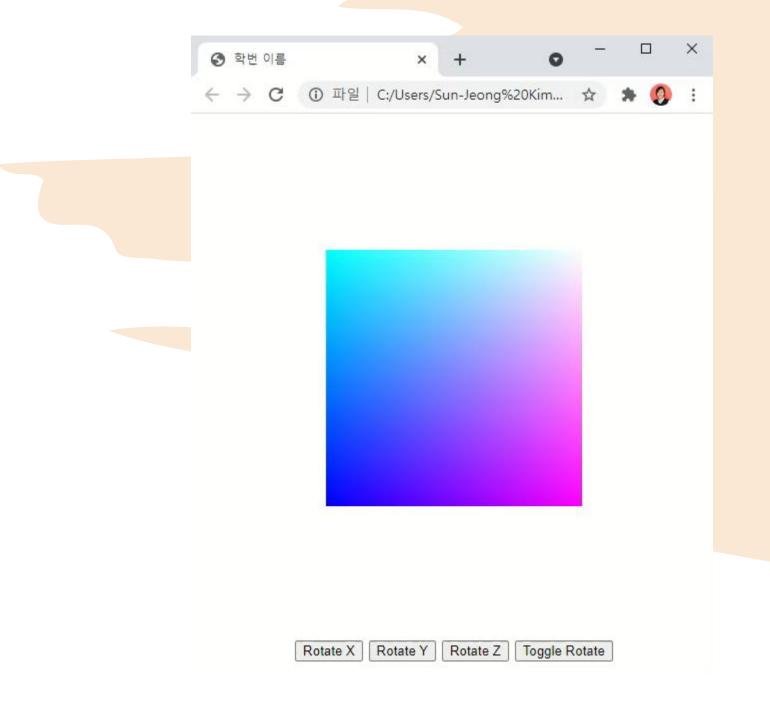


| /



File Edit Selection View Go Run Terminal Help light.js - Visual Studio Code П ... light.html JS light.js  $\times$ C: > Users > Sun-Jeong Kim > Desktop > CG > JS light.js > [∅] viewMatrix Hara Hilbar var gl; Transfer . var points = []; Commence of the last of the la var colors = []; FREE PROPERTY. مع THE RESERVE THE TAXABLE Name and Address of the Owner, where var axis = 0; var theta = [0, 0, 0];STREET, STREET, STREET var rotation = false; PROPERTY. 8 Control of the last of var viewMatrix, projectionMatrix; Part of Delicary was noticed 留 WEST var modelViewMatrixLoc, projectionMatrixLoc; 10 ARREST STATE OF THE REAL PROPERTY. DECEMBEL OF SEC. ... const eye = vec3(0.0, 0.0, 1.0); 11 PRODUCTION OF STREET const at = vec3(0.0, 0.0, 0.0); 12 const up = vec3(0.0, 1.0, 0.0); 13 14 15 var trballMatrix = mat4(1, 0, 0, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1); var numVertCubeTri; 16 17 window.onload = function init() 18 19 var canvas = document.getElementById("gl-canvas"); 20 21 22 gl = WebGLUtils.setupWebGL(canvas); if( !gl ) { 23 alert("WebGL isn't available!"); 24 25 26 generateColorCube(); 27 28 // virtual trackball 29 var trball = trackball(canvas.width, canvas.height); 30 31 var mouseDown = false; 32 canvas.addEventListener("mousedown", function (event) { 33 trball.start(event.clientX, event.clientY); 34 ⊗ 0 ∆ 0

```
File Edit Selection View Go Run Terminal Help
                                                                                                                                                                                                   light.js - Visual Studio Code
                                                                                                                                                                                                                                                                                                                                                                                                                                       □ ...
                  light.html
                                                              JS light.js
                                                                                            \times
                  C: > Users > Sun-Jeong Kim > Desktop > CG > JS light.js > [@] viewMatrix
                    117
                                                                                                                                                                                                                                                                                                                                                                                                                    Billian
                                                                                                                                                                                                                                                                                                                                                                                                                    'manaha
                                                 render();
                    118
                                                                                                                                                                                                                                                                                                                                                                                                                    Commence of the last of the la
                    119
                                      };
                                                                                                                                                                                                                                                                                                                                                                                                                      FREE PROPERTY.
مع
                    120
                                                                                                                                                                                                                                                                                                                                                                                                                      The second section in the second
                                                                                                                                                                                                                                                                                                                                                                                                                       Name and Address of the Owner, where
                    121
                                      function render() {
                                                 gl.clear(gl.COLOR_BUFFER_BIT | gl.DEPTH_BUFFER_BIT);
                                                                                                                                                                                                                                                                                                                                                                                                                      STATE OF STREET
                    122
                                                                                                                                                                                                                                                                                                                                                                                                                     Sandaran maran.
                    123
                                                                                                                                                                                                                                                                                                                                                                                                                      2007216 mm.
                                                                                                                                                                                                                                                                                                                                                                                                                      THE VALUE OF STREET
                                                 if( rotation ) theta[axis] += 2.0;
                    124
                                                                                                                                                                                                                                                                                                                                                                                                                      The second
                                                                                                                                                                                                                                                                                                                                                                                                                      Company of the last on
                    125
                                                 var rx = rotateX(theta[0]);
œ
                                                                                                                                                                                                                                                                                                                                                                                                                      PROFESSION OF STREET
                                                                                                                                                                                                                                                                                                                                                                                                                      WEST THE REST
                    126
                                                 var ry = rotateY(theta[1]);
                                                                                                                                                                                                                                                                                                                                                                                                                       ARREST STATE OF THE REAL PROPERTY.
                                                                                                                                                                                                                                                                                                                                                                                                                      DECEMBEL OF SEC. ...
                                                 var rz = rotateZ(theta[2]);
                    127
                                                                                                                                                                                                                                                                                                                                                                                                                      PRODUCTION OF STREET
                                                 modelViewMatrix = mult(ry, rx);
                    128
                                                 modelViewMatrix = mult(rz, modelViewMatrix);
                    129
                                                                                                                                                                                                                                                                                                                                                                                                                      modelViewMatrix = mult(viewMatrix, modelViewMatrix);
                    130
                                                 gl.uniformMatrix4fv(modelViewMatrixLoc, false, flatten(modelViewMatrix));
                    131
                    132
                    133
                                                 gl.drawArrays(gl.TRIANGLES, 0, points.length);
                   134
                    135
                                                 window.requestAnimationFrame(render);
                    136
                   137
                    138
                                      function generateColorCube() {
                    139
                                                 numVertCubeTri = 0;
                                                quad(1, 0, 3, 2);
                    140
                    141
                                                quad(2, 3, 7, 6);
                    142
                                                quad(3, 0, 4, 7);
                    143
                                                quad(4, 5, 6, 7);
                                                quad(5, 4, 0, 1);
                    144
                                                 quad(6, 5, 1, 2);
                    145
                    146
(2)
                    147
                                      function quad(a, b, c, d) {
                    148
                    149
                                                 vertexPos = [
                                                            vec4(-0.5, -0.5, -0.5, 1.0),
                    150
                                                           vec4( 0.5, -0.5, -0.5, 1.0)
⊗ 0 ∆ 0
                                                                                                                                                                                                                                                                                                   Ln 9, Col 15 (10 selected) Spaces: 4 UTF-8 CRLF JavaScript 🔊 🚨
```



### **OpenGL** Shading

- Need
  - Normals
  - <u>Material</u> properties
  - <u>Lights</u>
- State-based shading functions have been deprecated (glNormal, glMaterial, glLight)
- Get computer in application or in shaders

#### **Normalization**

- Cosine terms in lighting calculations can be computed using dot product
- Unit length vectors simplify calculation
- Usually we want to set the magnitudes to have unit length but
  - Length can be affected by transformations
  - Note that scaling does not preserved length
- GLSL has a <u>normalization</u> function

### Specifying a Directional Light Source

• For each light source, we can set an RGBA for the <u>diffuse</u>, <u>specular</u>, and <u>ambient</u> component, and for the <u>direction</u>

```
vec4 diffuse0 = vec4(1.0, 1.0, 0.0, 1.0);
vec4 ambient0 = vec4(1.0, 1.0, 1.0, 1.0, 1.0);
vec4 specular0 = vec4(0.0, 1.0, 1.0, 1.0);
vec4 light0_dir =vec4(1.0, 2.0, 3,0, 0.0);
```

#### **Direction** and Position

- The source colors are specified in RGBA
- The position is given in homogeneous coordinates
  - If w=1.0, we are specifying a finite <u>location</u>
  - If w=0.0, we are specifying a parallel source with the given direction vector
- The coefficient in distance terms are usually quadratic (1/( $k_c$ +  $k_l$ \*d+  $k_q$ \*d\*d)) where d is the distance from the point being rendered to the light source

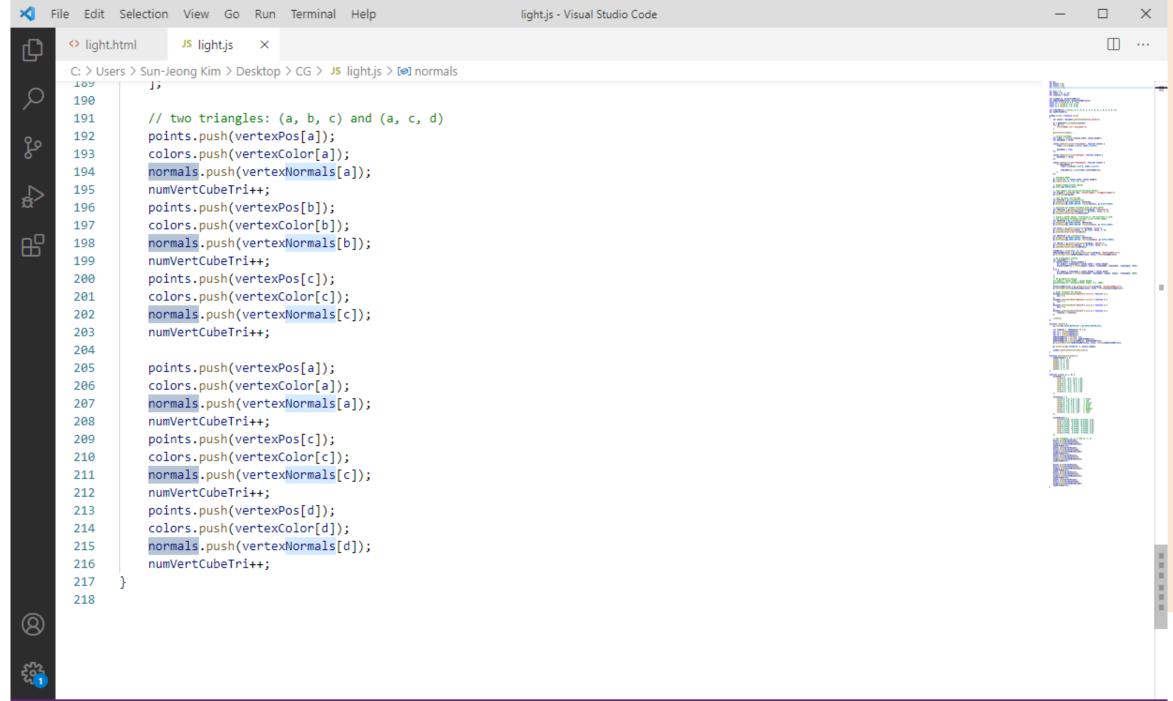
#### **Normal Vectors**

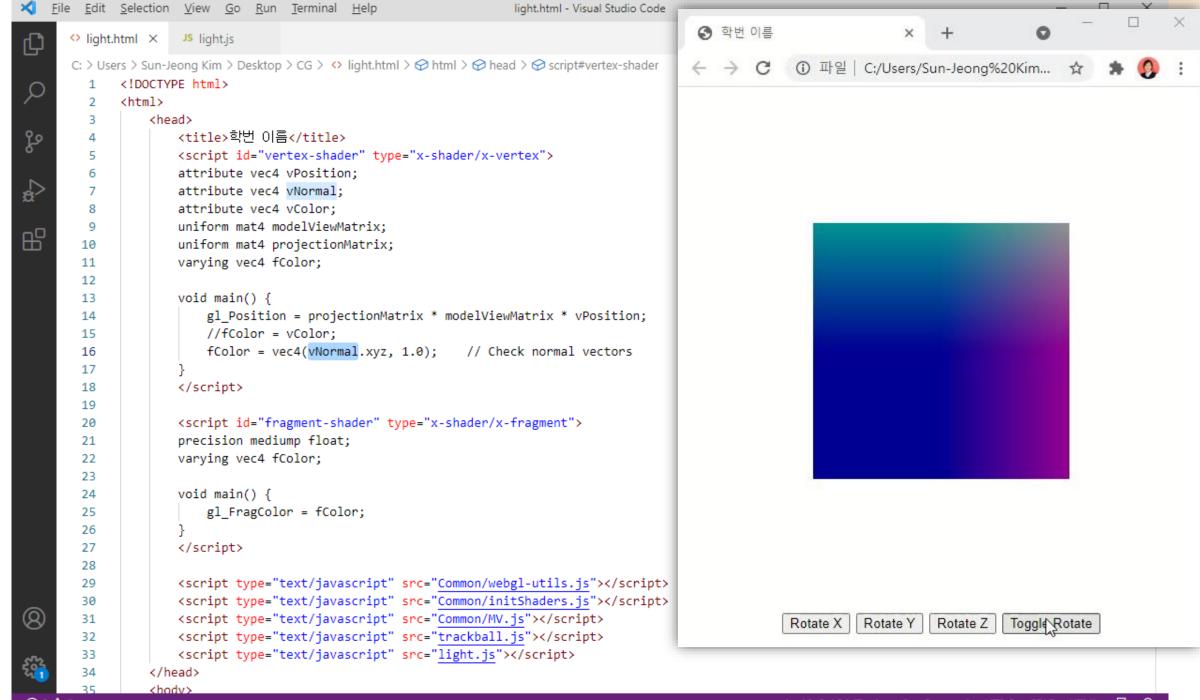
```
File Edit Selection View Go Run Terminal Help
                                                                   light.html - Visual Studio Code
   ♦ light.html × J5 light.js
   C: > Users > Sun-Jeong Kim > Desktop > CG > ↔ light.html > ↔ html > ↔ head > ↔ script#vertex-shader
          <!DOCTYPE html>
          <html>
               <head>
                  <title>학번 이름</title>
                  <script id="vertex-shader" type="x-shader/x-vertex">
                   attribute vec4 vPosition;
                   attribute vec4 vNormal;
      8
                   attribute vec4 vColor;
                  uniform mat4 modelViewMatrix;
                  uniform mat4 projectionMatrix;
     10
                  varying vec4 fColor;
     11
     12
                   void main() {
     13
                       gl_Position = projectionMatrix * modelViewMatrix * vPosition;
                       fColor = vColor;
     15
     16
     17
                   </script>
     18
                   <script id="fragment-shader" type="x-shader/x-fragment">
     19
     20
                   precision mediump float;
                   varying vec4 fColor;
     22
                   void main() {
                       gl FragColor = fColor;
     24
```

```
File Edit Selection View Go Run Terminal Help
                                                                                                                                                                                                                                                                                                                                                                                                                                                                     light.js - Visual Studio Code
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   П ...
                                          light.html
                                                                                                                                               JS light.js
                                                                                                                                                                                                                      ×
                                          C: > Users > Sun-Jeong Kim > Desktop > CG > JS light.js > [∅] normals
                                                                                       var gl;
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         var points = [];
                                                                                      var colors = [];
  عع
                                                                                        var normals = [];
                                                                                       var axis = 0;
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              MILES STATE
                                                                                       var theta = [0, 0, 0];
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              MIN 1915
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              THE VEHICLE SHE SET
                                                                                        var rotation = false;
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              STATE OF THE REAL PROPERTY.
                                                           9
留
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              AND ASSESSMENT OF THE PARTY.
                                                                                       var viewMatrix, projectionMatrix;
                                                     10
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              The State of State of
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                WESTERN THE TANK
                                                                                        var modelViewMatrixLoc, projectionMatrixLoc;
                                                     11
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 Assurement of the same of the 
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               MEDINGS OF THE PARTY OF THE PAR
                                                                                        const eye = vec3(0.0, 0.0, 1.0);
                                                    12
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            THE PERSON NAMED IN
                                                                                        const at = vec3(0.0, 0.0, 0.0);
                                                    13
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               Tele 1 1000
                                                                                        const up = vec3(0.0, 1.0, 0.0);
                                                     14
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              HE LEVE
                                                    15
                                                                                         var trballMatrix = mat4(1, 0, 0, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1);
                                                     16
                                                                                        var numVertCubeTri;
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          17
                                                     18
                                                                                        window.onload = function init()
                                                     19
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          20
                                                                                                                 var canvas = document.getElementById("gl-canvas");
                                                      21
                                                      22
                                                                                                                  gl = WebGLUtils.setupWebGL(canvas);
                                                      23
                                                                                                                 if(!gl) {
                                                      24
                                                     25
                                                                                                                                             alert("WebGL isn't available!");
                                                      26
                                                      27
                                                      28
                                                                                                                  generateColorCube();
                                                      29
                                                                                                                 // virtual trackball
                                                      30
                                                      31
                                                                                                                 var trball = trackball(canvas.width, canvas.height);
                                                     32
                                                                                                                 var mouseDown = false;
                                                      33
                                                     34
                                                                                                                   canvas.addEventListener("mousedown", function (event) {
                                                                                                                                             trhall.start(event.clientX, event.clientY):
⊗ 0 ∆ 0
```

```
light.js - Visual Studio Code
                  File Edit Selection View Go Run Terminal Help
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     П ...
                                       light.html
                                                                                                                                     JS light.js
                                                                                                                                                                                                    \times
                                        C: > Users > Sun-Jeong Kim > Desktop > CG > JS light.js > [∅] normals
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              Michael
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              The state of
                                                                                                        // Create a buffer object, initialize it, and associate it with
                                                73
                                                  74
                                                                                                        // the associated attribute variable in our vertex shader
  مړ
                                                                                                        var cBufferId = gl.createBuffer();
                                                 75
                                                76
                                                                                                        gl.bindBuffer(gl.ARRAY BUFFER, cBufferId);
                                                                                                         gl.bufferData(gl.ARRAY BUFFER, flatten(colors), gl.STATIC DRAW);
                                                 77
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  MATERIAL STREET
                                                  78
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   MANAGE TO SERVICE AND ADDRESS OF THE PARTY O
                                                                                                         var vColor = gl.getAttribLocation(program, "vColor");
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    THE PARTY OF THE P
                                                  79
                                                                                                         gl.vertexAttribPointer(vColor, 4, gl.FLOAT, false, 0, 0);
                                                  80
B
                                                  81
                                                                                                          gl.enableVertexAttribArray(vColor);
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   The State of the S
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     OE STATE OF THE PARTY OF THE PA
                                                  82
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     Assessment and the second
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    MEDIVEL IN SEC. ...
                                                                                                         var nBufferId = gl.createBuffer();
                                                  83
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                THE PERSON NAMED IN
                                                                                                         gl.bindBuffer(gl.ARRAY_BUFFER, nBufferId);
                                                  84
                                                                                                          gl.bufferData(gl.ARRAY_BUFFER, flatten(normals), gl.STATIC_DRAW);
                                                  85
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  HE Laws
                                                  86
                                                                                                         var vNormal = gl.getAttribLocation(program, "vNormal");
                                                  87
                                                                                                          gl.vertexAttribPointer(vNormal, 4, gl.FLOAT, false, 0, 0);
                                                  88
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               gl.enableVertexAttribArray(vNormal);
                                                  89
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  THE
                                                  90
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                viewMatrix = lookAt(eye, at, up);
                                                  91
                                                                                                         modelViewMatrixLoc = gl.getUniformLocation(program, "modelViewMatrix");
                                                  92
                                                                                                         gl.uniformMatrix4fv(modelViewMatrixLoc, false, flatten(viewMatrix));
                                                  93
                                                  94
                                                                                                         // 3D orthographic viewing
                                                  95
                                                                                                        var viewLength = 1.0;
                                                 96
                                                 97
                                                                                                         if (canvas.width > canvas.height) {
                                                                                                                                 var aspect = viewLength * canvas.width / canvas.height;
                                                  98
                                                                                                                                 projectionMatrix = ortho(-aspect, aspect, -viewLength, viewLength, -viewLength, 1000);
                                                 99
                                           100
                                           101
                                                                                                          else {
                                                                                                                                 var aspect = viewLength * canvas.height / canvas.width;
                                           102
                                           103
                                                                                                                                 projectionMatrix = ortho(-viewLength, viewLength, -aspect, aspect, -viewLength, 1000);
                                           104
                                           105
                                                                                                            // 3D perspective viewing
 ⊗ 0 ∆ 0
```

X File Edit Selection View Go Run Terminal Help light.js - Visual Studio Code П ... light.html JS light.js  $\times$ C: > Users > Sun-Jeong Kim > Desktop > CG > JS light.js > [@] normals 156 80042 157 function quad(a, b, c, d) { vertexPos = [ 158 - 20 مع vec4(-0.5, -0.5, -0.5, 1.0), 159 The second second TATALOGIC SECTIONS Table 1 to 1 vec4( 0.5, -0.5, -0.5, 1.0), 160 William or other vec4( 0.5, 0.5, -0.5, 1.0), 161 A STATE OF THE PARTY OF THE PAR vec4(-0.5, 0.5, -0.5, 1.0), 162 AND DESCRIPTION OF THE PARTY OF 1200 DE .... vec4(-0.5, -0.5, 0.5, 1.0), THE VALUE OF THE PARTY. 163 The second 164 vec4( 0.5, -0.5, 0.5, 1.0), STATE OF THE REAL PROPERTY. 165 vec4( 0.5, 0.5, 0.5, 1.0), AND ADDRESS OF THE OWNER. The State of WE SHOW THE TANK 166 vec4(-0.5, 0.5, 0.5, 1.0) Assurance and the second DECEMBEL OF SEC. ... 167 ]; THE PERSON NAMED IN 168 THE RESERVE AND ADDRESS OF THE PARTY OF THE vertexColor = [ 169 III Leve 170 vec4(0.0, 0.0, 0.0, 1.0), // black vec4(1.0, 0.0, 0.0, 1.0), 171 // red vec4(1.0, 1.0, 0.0, 1.0), // yellow 172 173 vec4(0.0, 1.0, 0.0, 1.0), // green THE F vec4(0.0, 0.0, 1.0, 1.0), // blue 174 175 vec4(1.0, 0.0, 1.0, 1.0), // magenta 1 100. 1 100. 1 100. 1 100. 1 100. 176 vec4(1.0, 1.0, 1.0, 1.0), // white 177 vec4(0.0, 1.0, 1.0, 1.0) // cyan ]; 178 179 vertexNormals = [ 180 181 vec4(-0.57735, -0.57735, -0.57735, 0.0), 182 vec4( 0.57735, -0.57735, -0.57735, 0.0), vec4( 0.57735, 0.57735, -0.57735, 0.0), 183 vec4(-0.57735, 0.57735, -0.57735, 0.0), 184 vec4(-0.57735, -0.57735, 0.57735, 0.0), 185 vec4( 0.57735, -0.57735, 0.57735, 0.0), 186 187 vec4( 0.57735, 0.57735, 0.57735, 0.0), 188 vec4(-0.57735, 0.57735, 0.57735, 0.0) 189 ⊗ 0 ∆ 0

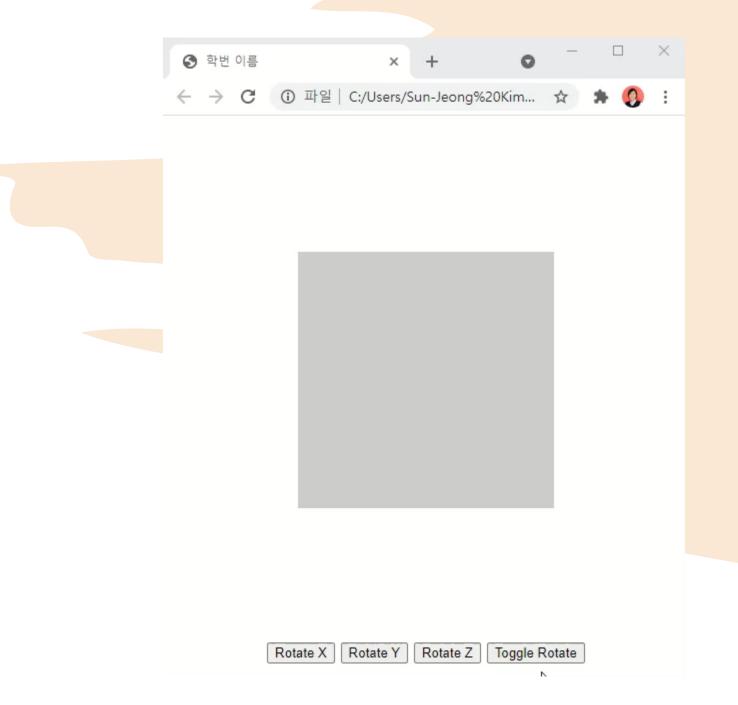




#### **Ambient Reflection**

```
Edit Selection View Go Run Terminal Help
                                                                light.html - Visual Studio Code
♦ light.html × J5 light.js
C: > Users > Sun-Jeong Kim > Desktop > CG > ♦ light.html > ♦ html > ♦ head > ♦ script#vertex-shader
       <!DOCTYPE html>
       <html>
           <head>
               <title>학번 이름</title>
  4
               <script id="vertex-shader" type="x-shader/x-vertex">
                                                                                                                                                MINIE
               attribute vec4 vPosition;
               attribute vec4 vNormal;
  8
               attribute vec4 vColor;
               uniform mat4 modelViewMatrix;
               uniform mat4 projectionMatrix;
 10
               varying vec4 fColor;
 11
 12
               uniform vec4 lightAmbient;
 13
               void main() {
 15
                   gl_Position = projectionMatrix * modelViewMatrix * vPosition;
 16
                   //fColor = vColor;
 17
                   fColor = lightAmbient;
 18
 19
 20
               </script>
               <script id="fragment-shader" type="x-shader/x-fragment">
 22
               precision mediump float;
 23
               varying vec4 fColor;
 24
```

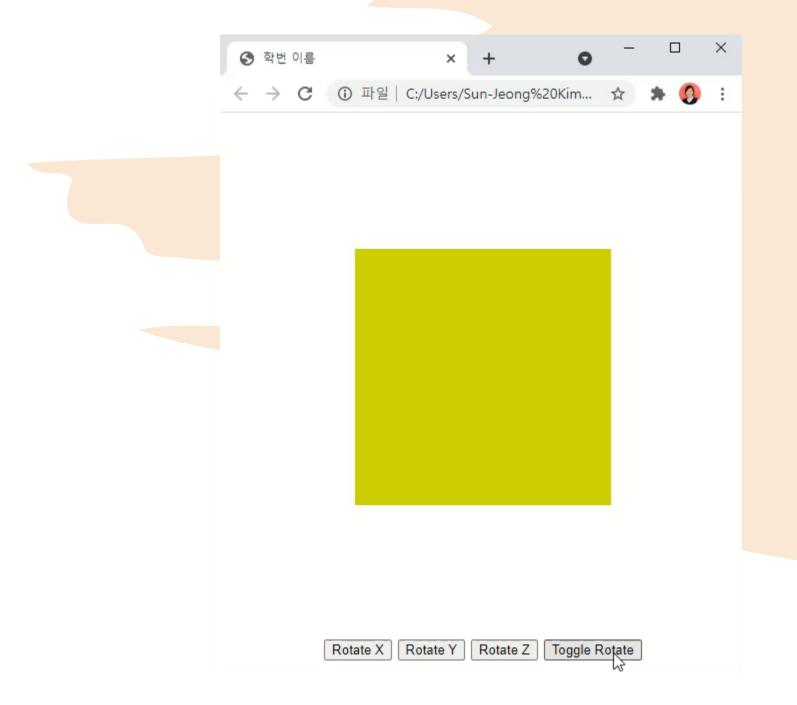
```
<u>File Edit Selection View Go Run Terminal Help</u>
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   light.js - Visual Studio Code
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        ...
                                                light.html
                                                                                                                                                                   JS light.js
                                                                                                                                                                                                                                                   \times
                                                C: > Users > Sun-Jeong Kim > Desktop > CG > JS light.js > ♥ init
                                                    126
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        BUNAS.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        127
                                                                                                                                   setLighting(program);
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            - 20
                                                     128
   عع
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              Marian Santa
                                                    129
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              No. of Street, Street,
                                                                                                                                 render();
                                                     130
                                                    131
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              ACCRECATE VALUE OF THE PARTY OF
                                                                                                     function render() {
                                                     132
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              THE VALUE OF STREET
                                                                                                                                  gl.clear(gl.COLOR_BUFFER_BIT | gl.DEPTH_BUFFER_BIT);
                                                     133
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              The second
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              STATE OF THE REAL PROPERTY.
                                                     134
œ
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            AND ADDRESS OF THE OWNER.
                                                    135
                                                                                                                                 if( rotation ) theta[axis] += 2.0;
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              The State of State of
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               WE SHOW THE TAX TO THE
                                                     136
                                                                                                                                 var rx = rotateX(theta[0]);
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                Assessment organization rate and reserve
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              DECEMBEL OF SEC. ...
                                                     137
                                                                                                                                 var ry = rotateY(theta[1]);
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            THE PERSON NAMED IN
                                                    138
                                                                                                                                 var rz = rotateZ(theta[2]);
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               Tele 1 1000
                                                    139
                                                                                                                                 modelViewMatrix = mult(ry, rx);
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         modelViewMatrix = mult(rz, modelViewMatrix);
                                                     140
                                                                                                                                 modelViewMatrix = mult(viewMatrix, modelViewMatrix);
                                                     141
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          A STREET, SQUARE, SPINSTER, SPINSTER
                                                                                                                                  gl.uniformMatrix4fv(modelViewMatrixLoc, false, flatten(modelViewMatrix));
                                                    142
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          143
                                                                                                                                  gl.drawArrays(gl.TRIANGLES, 0, points.length);
                                                     144
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              THE
                                                    145
                                                    146
                                                                                                                                 window.requestAnimationFrame(render);
                                                     147
                                                     148
                                                                                                     function setLighting(program) {
                                                     149
                                                                                                                                 var lightAmbient = [0.8, 0.8, 0.8, 1.0];
                                                    150
                                                     151
                                                                                                                                 var lightAmbientLoc = gl.getUniformLocation(program, "lightAmbient");
                                                   152
                                                    153
                                                                                                                                 gl.uniform4fv(lightAmbientLoc, lightAmbient);
                                                   154
                                                    155
(8)
                                                                                                     function generateColorCube() {
                                                    156
                                                                                                                                  numVertCubeTri = 0;
                                                    157
                                                                                                                                 quad(1, 0, 3, 2);
                                                     158
                                                     159
                                                                                                                                 quad(2, 3, 7, 6);
  ⊗ 0 ∆ 0
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   Ln 127, Col 16 (11 selected) Spaces: 4 UTF-8 CRLF JavaScript 🔊 🚨
```



#### **Materials**

```
Edit Selection View Go Run Terminal Help
                                                                light.html - Visual Studio Code
◇ light.html ×
               JS light.js
C: > Users > Sun-Jeong Kim > Desktop > CG > ♦ light.html > ♦ html > ♦ head > ♦ script#vertex-shader
       <!DOCTYPE html>
       <html>
  3
           <head>
               <title>학번 이름</title>
  4
               <script id="vertex-shader" type="x-shader/x-vertex">
               attribute vec4 vPosition;
               attribute vec4 vNormal;
  8
               attribute vec4 vColor;
               uniform mat4 modelViewMatrix;
               uniform mat4 projectionMatrix;
 10
               varying vec4 fColor;
 11
 12
               uniform vec4 lightAmbient;
 13
               uniform vec4 matAmbient;
 15
               void main() {
 16
                   gl_Position = projectionMatrix * modelViewMatrix * vPosition;
 17
                   //fColor = vColor;
 18
                   fColor = lightAmbient * matAmbient;
 19
 20
               </script>
 22
               <script id="fragment-shader" type="x-shader/x-fragment">
 23
               precision mediump float;
 24
```

```
<u>File Edit Selection View Go Run Terminal Help</u>
                                                                                                                                                                                                                                                                                                                                                                                                   light.js - Visual Studio Code
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   П ...
                                    light.html
                                                                                                                          JS light.js
                                                                                                                                                                                      \times
                                     C: > Users > Sun-Jeong Kim > Desktop > CG > J5 light.js > 分 setLighting > [ø] matAmbient
                                        126
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              BUNAS.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              127
                                                                                                 setLighting(program);
                                        128
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 - 20
  عع
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  Marian and the same
                                        129
                                                                                                 render();
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  No. of Street, Street,
                                        130
                                        131
                                                                            function render() {
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  ACCRECATE VALUE OF THE PARTY OF
                                        132
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  gl.clear(gl.COLOR_BUFFER_BIT | gl.DEPTH_BUFFER_BIT);
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  THE VALUE OF STREET
                                        133
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  The second
                                        134
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  AND DESCRIPTION OF THE
B
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 AND ADDRESS OF THE OWNER, WHEN
                                                                                                if( rotation ) theta[axis] += 2.0;
                                       135
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  PROFESSION OF THE
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   WE SHOW THE TAX ---
                                                                                                 var rx = rotateX(theta[0]);
                                        136
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    Assessment organization and the same
                                                                                                 var ry = rotateY(theta[1]);
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   MONTH OF THE PARTY OF THE PARTY
                                        137
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 THE PERSON NAMED IN
                                                                                                 var rz = rotateZ(theta[2]);
                                        138
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   Tele 1 1000
                                                                                                 modelViewMatrix = mult(ry, rx);
                                        139
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               modelViewMatrix = mult(rz, modelViewMatrix);
                                        140
                                                                                                 modelViewMatrix = mult(viewMatrix, modelViewMatrix);
                                        141
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               WARRIST CO. INC.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                ALCOHOL: N
                                                                                                 gl.uniformMatrix4fv(modelViewMatrixLoc, false, flatten(modelViewMatrix));
                                       142
                                        143
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                144
                                                                                                 gl.drawArrays(gl.TRIANGLES, 0, points.length);
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  THE
                                        145
                                        146
                                                                                                 window.requestAnimationFrame(render);
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   147
                                       148
                                                                            function setLighting(program) {
                                        149
                                                                                                 var lightAmbient = [0.8, 0.8, 0.8, 1.0];
                                       150
                                                                                                 var matAmbient = [1.0, 1.0, 0.0, 1.0];
                                        151
                                        152
                                       153
                                                                                                 var lightAmbientLoc = gl.getUniformLocation(program, "lightAmbient");
                                                                                                 gl.uniform4fv(lightAmbientLoc, lightAmbient);
                                       154
                                       155
                                                                                                 var matAmbientLoc = gl.getUniformLocation(program, "matAmbient");
(2)
                                                                                                 gl.uniform4fv(matAmbientLoc, matAmbient);
                                       156
                                       157
                                        158
                                                                           function generateColorCube() {
                                                                                                 numVertCubeTri = 0;
 ⊗ 0 ∆ 0
```

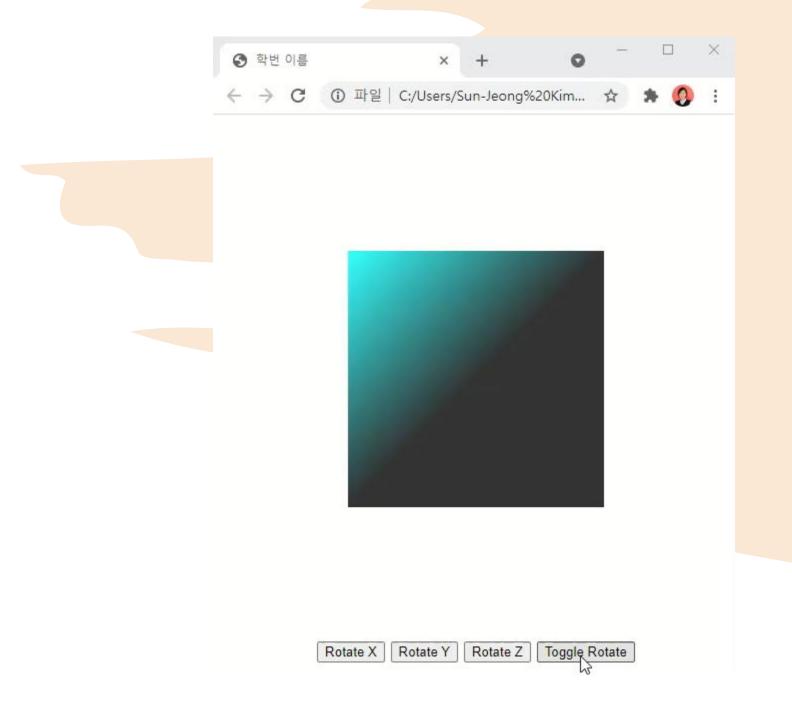


#### **Diffuse** Reflection

```
<script id="vertex-shader" type="x-shader/x-vertex">
             attribute vec4 vPosition;
             attribute vec4 vNormal;
             attribute vec4 vColor;
             uniform mat4 modelViewMatrix;
             uniform mat4 projectionMatrix;
11
             varying vec4 fColor;
12
             uniform vec4 lightDir, lightAmbient, lightDiffuse;
13
             uniform vec4 matAmbient, matDiffuse;
14
15
             void main() {
16
                 gl_Position = projectionMatrix * modelViewMatrix * vPosition;
17
                 //fColor = vColor;
18
                 vec4 ambient = lightAmbient * matAmbient;
19
20
                 vec3 N = normalize(modelViewMatrix * vNormal).xyz;
21
                 vec3 L = normalize(lightDir.xyz);
22
                 float kd = max(dot(L, N), 0.0);
                 vec4 diffuse = kd * lightDiffuse * matDiffuse;
24
25
                 fColor = ambient + diffuse;
26
                 fColor.a = 1.0;
28
             </script>
29
30
             <script id="fragment-shader" type="x-shader/x-fragment">
31
             precision mediump float;
32
               . . . . . . .
```



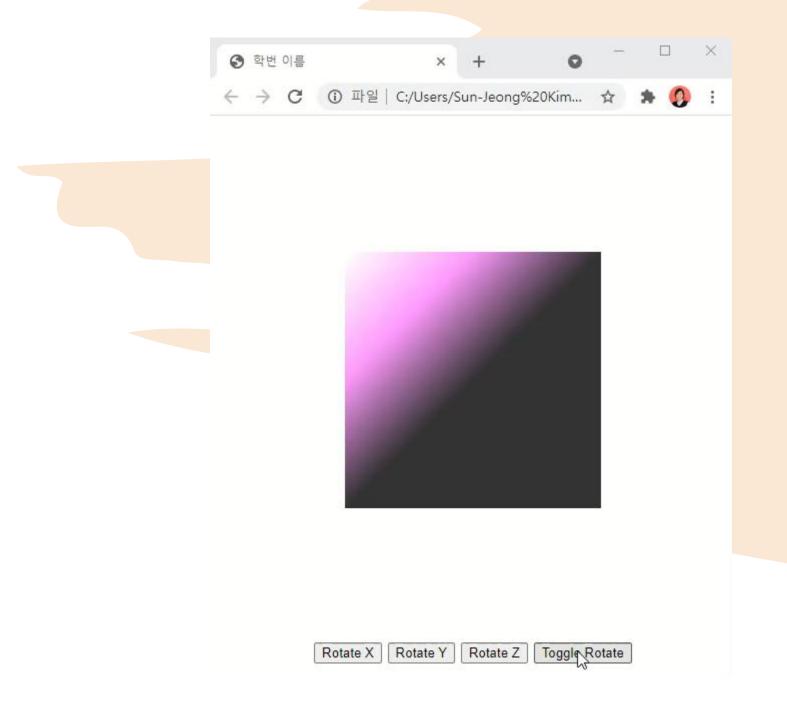
```
<u>File Edit Selection View Go Run Terminal Help</u>
                                                                                                                                                                             light.js - Visual Studio Code
                                                                                                                                                                                                                                                                                                                                                                                       П ...
                light.html
                                                       JS light.js
                                                                                 ×
                C: > Users > Sun-Jeong Kim > Desktop > CG > JS light.js > ♦ setLighting > [ø] lightDir
                  148
                                                                                                                                                                                                                                                                                                                                                                      BUNAS.
                                                                                                                                                                                                                                                                                                                                                                      function setLighting(program) {
                  149
                                           var lightDir = [-1.0, 1.0, 0.0, 0.0];
                  150
                                                                                                                                                                                                                                                                                                                                                                        5 AU
 مع
                                           var lightAmbient = [0.2, 0.2, 0.2, 1.0];
                                                                                                                                                                                                                                                                                                                                                                        THE PERSON NAMED IN
                  151
                                                                                                                                                                                                                                                                                                                                                                        The second section in the
                 152
                                           var lightDiffuse = [1.0, 1.0, 1.0, 1.0];
                  153
                                           var matAmbient = [1.0, 1.0, 1.0, 1.0];
                                                                                                                                                                                                                                                                                                                                                                        MILLSON STREET
                  154
                                                                                                                                                                                                                                                                                                                                                                        var matDiffuse = [0.0, 1.0, 1.0, 1.0];
                                                                                                                                                                                                                                                                                                                                                                        MANAGEMENT.
                  155
                  156
                                                                                                                                                                                                                                                                                                                                                                        STATE OF THE REAL PROPERTY.
B
                                           var lightDirLoc = gl.getUniformLocation(program, "lightDir");
                                                                                                                                                                                                                                                                                                                                                                        And Address of the Owner,
                 157
                                                                                                                                                                                                                                                                                                                                                                        PROFESSION OF THE
                                           gl.uniform4fv(lightDirLoc, lightDir);
                                                                                                                                                                                                                                                                                                                                                                         WE SHOW THE TAX ---
                  158
                                                                                                                                                                                                                                                                                                                                                                          Assessment and the second
                                                                                                                                                                                                                                                                                                                                                                         MEDINGS OF SEC.
                                           var lightAmbientLoc = gl.getUniformLocation(program, "lightAmbient");
                  159
                                                                                                                                                                                                                                                                                                                                                                        THE PERSON NAMED IN
                                            gl.uniform4fv(lightAmbientLoc, lightAmbient);
                  160
                                           var lightDiffuseLoc = gl.getUniformLocation(program, "lightDiffuse");
                  161
                                                                                                                                                                                                                                                                                                                                                                       H. Leve-
                                           gl.uniform4fv(lightDiffuseLoc, lightDiffuse);
                  162
                 163
                                                                                                                                                                                                                                                                                                                                                                       BENEFIT FETETE
                                           var matAmbientLoc = gl.getUniformLocation(program, "matAmbient");
                 164
                                           gl.uniform4fv(matAmbientLoc, matAmbient);
                                                                                                                                                                                                                                                                                                                                                                        CONTRACTOR OF THE PARTY OF THE 
                  165
                                           var matDiffuseLoc = gl.getUniformLocation(program, "matDiffuse");
                  166
                                                                                                                                                                                                                                                                                                                                                                       gl.uniform4fv(matDiffuseLoc, matDiffuse);
                  167
                 168
                                                                                                                                                                                                                                                                                                                                                                        THE F
                  169
                                                                                                                                                                                                                                                                                                                                                                        function generateColorCube() {
                  170
                 171
                                           numVertCubeTri = 0;
                 172
                                           quad(1, 0, 3, 2);
                  173
                                           quad(2, 3, 7, 6);
                 174
                                           quad(3, 0, 4, 7);
                 175
                                           quad(4, 5, 6, 7);
                  176
                                           quad(5, 4, 0, 1);
                 177
                                           quad(6, 5, 1, 2);
(2)
                 178
                 179
                                 function quad(a, b, c, d) {
                 180
                                           vertexPos = [
                 181
                                                     vec4(-0.5, -0.5, -0.5, 1.0)
⊗ 0 ∆ 0
```



# Specular Reflection

```
Edit Selection View Go Run Terminal Help
                                                                light.html - Visual Studio Code
○ light.html ×
                JS light.js
C: > Users > Sun-Jeong Kim > Desktop > CG > ↔ light.html > � html > � head > � script#vertex-shader
               <script id="vertex-shader" type="x-shader/x-vertex">
  6
               attribute vec4 vPosition;
               attribute vec4 vNormal:
  8
               attribute vec4 vColor:
  9
               uniform mat4 modelViewMatrix;
 10
               uniform mat4 projectionMatrix;
               varying vec4 fColor;
 11
 12
 13
               uniform vec4 lightDir, lightAmbient, lightDiffuse, lightSpecular;
 14
               uniform vec4 matAmbient, matDiffuse, matSpecular;
 15
               uniform float matShininess;
 16
 17
               void main() {
                   gl_Position = projectionMatrix * modelViewMatrix * vPosition;
 18
                   //fColor = vColor;
 19
 20
                   vec4 ambient = lightAmbient * matAmbient;
 21
                   vec3 N = normalize(modelViewMatrix * vNormal).xyz;
 22
 23
                   vec3 L = normalize(lightDir.xyz);
                   float kd = max(dot(L, N), 0.0);
 24
                   vec4 diffuse = kd * lightDiffuse * matDiffuse;
 25
 26
                   vec3 V = normalize(modelViewMatrix*vPosition).xyz;
 27
                                                                             // origin: camera position
                   vec3 H = normalize(L - V).xyz;
 28
 29
                   float ks = pow(max(dot(N, H), 0.0), matShininess);
                   vec4 specular = ks * lightSpecular * matSpecular;
 30
 31
                   if (dot(L, N) < 0.0)
                                            specular = vec4(0.0, 0.0, 0.0, 1.0);
 32
 33
                   fColor = ambient + diffuse + specular;
 34
 35
                   fColor.a = 1.0:
 36
               </script>
 37
 38
                /scrint id-"fragment-shader" type-"y-shader/y-fragment"
                                                                                                      Ln '
```

```
<u>File Edit Selection View Go Run Terminal Help</u>
                                                                              light.js - Visual Studio Code
                                                                                                                                                                        П ...
       light.html
                        JS light.js
                                    ×
       C: > Users > Sun-Jeong Kim > Desktop > CG > JS light.js > ♦ setLighting > [a] matShininess
       148
                                                                                                                                                                Milhar
                                                                                                                                                                function setLighting(program) {
        149
        150
                   var lightDir = [-1.0, 1.0, 0.0, 0.0];
                                                                                                                                                                 V-811
                                                                                                                                                                 Marie Control
                   var lightAmbient = [0.2, 0.2, 0.2, 1.0];
       151
                                                                                                                                                                 The reserved to the last
                   var lightDiffuse = [1.0, 1.0, 1.0, 1.0];
        152
                   var lightSpecular = [1.0, 1.0, 1.0, 1.0];
        153
                                                                                                                                                                 MATCH STREET
        154
                                                                                                                                                                 1200 Park
                                                                                                                                                                 CHRISTIAN STATE
        155
                   var matAmbient = [1.0, 1.0, 1.0, 1.0];
                                                                                                                                                                 THE RESERVOISE.
                   var matDiffuse = [1.0, 1.0, 1.0, 1.0];
        156
                                                                                                                                                                 STATE OF THE REAL PROPERTY.
                                                                                                                                                                 And Advanced Print Block
       157
                   var matSpecular = [1.0, 0.0, 1.0, 1.0];
                                                                                                                                                                 PROFESSION OF STREET
                                                                                                                                                                 WE SHIP THE TANK
                   var matShininess = 100.0;
       158
                                                                                                                                                                  Assurance and the second
                                                                                                                                                                 SECRETARIAN SECTION ...
        159
                                                                                                                                                                 var lightDirLoc = gl.getUniformLocation(program, "lightDir");
        160
                                                                                                                                                                 Total Control
                   gl.uniform4fv(lightDirLoc, lightDir);
       161
                                                                                                                                                                 Total Control of the last
                                                                                                                                                                 He Leve
                   var lightAmbientLoc = gl.getUniformLocation(program, "lightAmbient");
        162
                   gl.uniform4fv(lightAmbientLoc, lightAmbient);
        163
                                                                                                                                                                THE WOOD
                   var lightDiffuseLoc = gl.getUniformLocation(program, "lightDiffuse");
        164
                                                                                                                                                                 BEELINA NA NA
                   gl.uniform4fv(lightDiffuseLoc, lightDiffuse);
       165
                                                                                                                                                                 var lightSpecularLoc = gl.getUniformLocation(program, "lightSpecular");
        166
                                                                                                                                                                 gl.uniform4fv(lightSpecularLoc, lightSpecular);
        167
                                                                                                                                                                 168
                                                                                                                                                                 THE F
       169
                   var matAmbientLoc = gl.getUniformLocation(program, "matAmbient");
                   gl.uniform4fv(matAmbientLoc, matAmbient);
       170
                                                                                                                                                                 var matDiffuseLoc = gl.getUniformLocation(program, "matDiffuse");
       171
                                                                                                                                                                 1 746.
1 140.
2 140.
2 140.
2 140.
                   gl.uniform4fv(matDiffuseLoc, matDiffuse);
       172
       173
                   var matSpecularLoc = gl.getUniformLocation(program, "matSpecular");
                   gl.uniform4fv(matSpecularLoc, matSpecular);
       174
                   var matShininessLoc = gl.getUniformLocation(program, "matShininess");
       175
                   gl.uniform1f(matShininessLoc, matShininess);
       176
       177
(8)
        178
               function generateColorCube() {
       179
        180
                   numVertCubeTri = 0;
                   quad(1, 0, 3, 2);
        181
                   quad(2, 3, 7, 6);
⊗ 0 ∆ 0
```



#### 연습 문제 (1)

- light.js에 있는 setLighting() 함수에서,
  - lightDir의 값을 변경하면, 결과가 어떻게 바뀌는지 설명하시오.
    - 예) var lightDir = vec4(1.0, 0.0, 0.0, 0.0);
  - lightAmbient, lightDiffuse, lightSpecular의 값을 변경하면, 결과가 어떻게 바뀌는지 설명하시오.
    - 예) var lightAmbient = vec4(1.0, 0.0, 0.0, 1.0); var lightDiffuse = vec4(0.0, 1.0, 0.0, 1.0); var lightSpecular = vec4(0.0, 0.0, 1.0, 1.0);
  - matShininess의 값을 변경하면, 결과가 어떻게 바뀌는지 설명하시오.
    - 예) var matShininess = 20.0

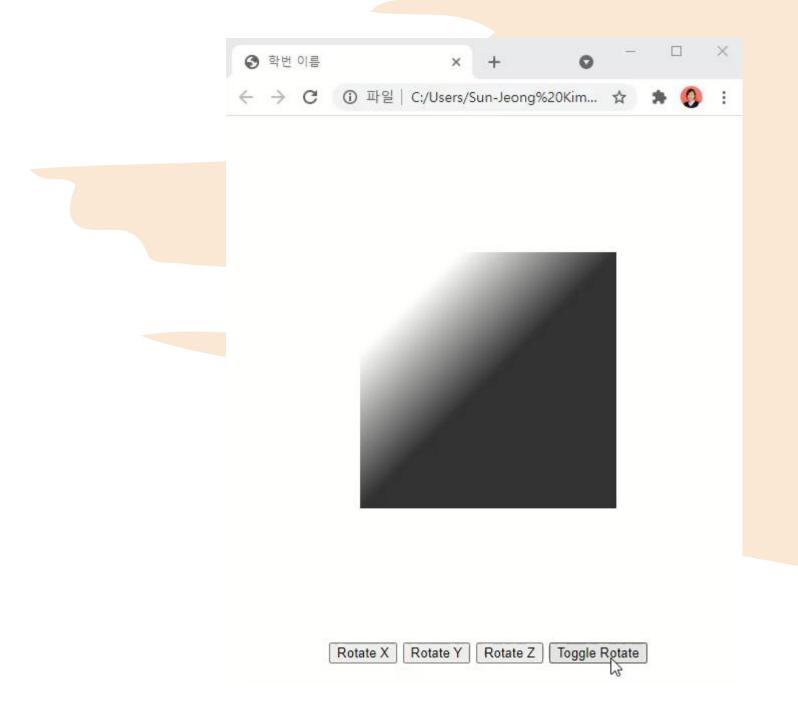
#### **Point Light**

```
♦ light.html × JS light.js
C: > Users > Sun-Jeong Kim > Desktop > CG > ♦ light.html > ♦ html > ♦ head > ♦ script#vertex-shader
       <!DOCTYPE html>
       <html>
           <head>
               <title>학번 이름</title>
  4
               <script id="vertex-shader" type="x-shader/x-vertex">
  5
               attribute vec4 vPosition;
   6
               attribute vec4 vNormal;
  7
               attribute vec4 vColor;
  8
               uniform mat4 modelViewMatrix;
  9
               uniform mat4 projectionMatrix;
 10
 11
               varying vec4 fColor;
 12
               uniform vec4 lightPos, lightAmbient, lightDiffuse, lightSpecular;
 13
               uniform vec3 kAtten;
 14
 15
               uniform vec4 matAmbient, matDiffuse, matSpecular;
               uniform float matShininess;
 16
 17
               void main() {
 18
                   gl_Position = projectionMatrix * modelViewMatrix * vPosition;
 19
                   //fColor = vColor;
 20
                   vec4 ambient = lightAmbient * matAmbient;
 21
 22
                   vec3 N = normalize((modelViewMatrix * vNormal).xyz);
 23
                   if (lightPos.w == 0.0) { // directional light
 24
                       vec3 L = normalize(lightPos.xyz);
 25
                       float kd = max(dot(L, N), 0.0);
 26
                       vec4 diffuse = kd * lightDiffuse * matDiffuse;
 27
 28
                       vec3 V = normalize((modelViewMatrix * vPosition).xyz); // origin: camera
 29
                       vec3 H = normalize(L - V);
 30
                       float ks = pow(max(dot(N, H), 0.0), matShininess);
 31
                       vec4 specular = ks * lightSpecular * matSpecular;
 32
 33
```

light.html - Visual Studio Code

Edit Selection View Go Run Terminal Help

<u>File Edit Selection View Go Run Terminal Help</u> light.js - Visual Studio Code П ... ◇ light.html JS light.is  $\times$ C: > Users > Sun-Jeong Kim > Desktop > CG > JS light.js > ♦ setLighting > [ø] attenLoc 148 50000 149 function setLighting(program) { E MANAGEMENT OF THE PARTY OF TH var lightPos = [-1.0, 1.0, 0.0, 1.0]; 150 مع var lightAmbient = [0.2, 0.2, 0.2, 1.0]; 151 Total Street Company of the last var lightDiffuse = [1.0, 1.0, 1.0, 1.0]; 152 William or or or 153 var lightSpecular = [1.0, 1.0, 1.0, 1.0]; A STATE OF THE PARTY OF THE PAR Supplementary Age 154 (2007) 200 Tonas ..... PROVINCE: 155 var matAmbient = [1.0, 1.0, 1.0, 1.0];THE RESERVE OF THE PERSON NAMED OF THE PERSON var matDiffuse = [1.0, 1.0, 1.0, 1.0]; AND DESCRIPTION OF THE 156 出 Market Street, see AND ASSESSMENT OF THE OWNER, WHEN THE var matSpecular = [1.0, 1.0, 1.0, 1.0]; 157 PROFESSION OF STREET WE SHOW IN THE CO. 158 var matShininess = 20.0; "Assurement of the second of DECEMBER OF .... 159 AND DESCRIPTION OF PERSONS ASSESSED. var lightPosLoc = gl.getUniformLocation(program, "lightPos"); 160 the property of the last gl.uniform4fv(lightPosLoc, lightPos); 161 Total Same and HE Law 162 var attenLoc = gl.getUniformLocation(program, "kAtten"); gl.uniform3f(attenLoc, 0.0, 0.0, 1.0); 163 and the latest and th var lightAmbientLoc = gl.getUniformLocation(program, "lightAmbient"); BELVANARA. 164 gl.uniform4fv(lightAmbientLoc, lightAmbient); 165 var lightDiffuseLoc = gl.getUniformLocation(program, "lightDiffuse"); 166 gl.uniform4fv(lightDiffuseLoc, lightDiffuse); 167 var lightSpecularLoc = gl.getUniformLocation(program, "lightSpecular"); 168 169 gl.uniform4fv(lightSpecularLoc, lightSpecular); 170 var matAmbientLoc = gl.getUniformLocation(program, "matAmbient"); 171 172 gl.uniform4fv(matAmbientLoc, matAmbient); var matDiffuseLoc = gl.getUniformLocation(program, "matDiffuse"); 173 gl.uniform4fv(matDiffuseLoc, matDiffuse); 174 var matSpecularLoc = gl.getUniformLocation(program, "matSpecular"); 175 gl.uniform4fv(matSpecularLoc, matSpecular); 176 var matShininessLoc = gl.getUniformLocation(program, "matShininess"); 177 gl.uniform1f(matShininessLoc, matShininess); 178 179 180



### 연습 문제 (2)

- light.js에 있는 setLighting() 함수에서,
  - lightPos의 값을 변경하면, 결과가 어떻게 바뀌는지 설명하시오.
    - 예) var lightPos = vec4(1.0, 0.0, 0.0, 1.0);
  - kAtten의 값을 변경하면, 결과가 어떻게 바뀌는지 설명하시오.
    - 예) gl.uniform3f(attenLoc, 1.0, 0.0, 0.0);

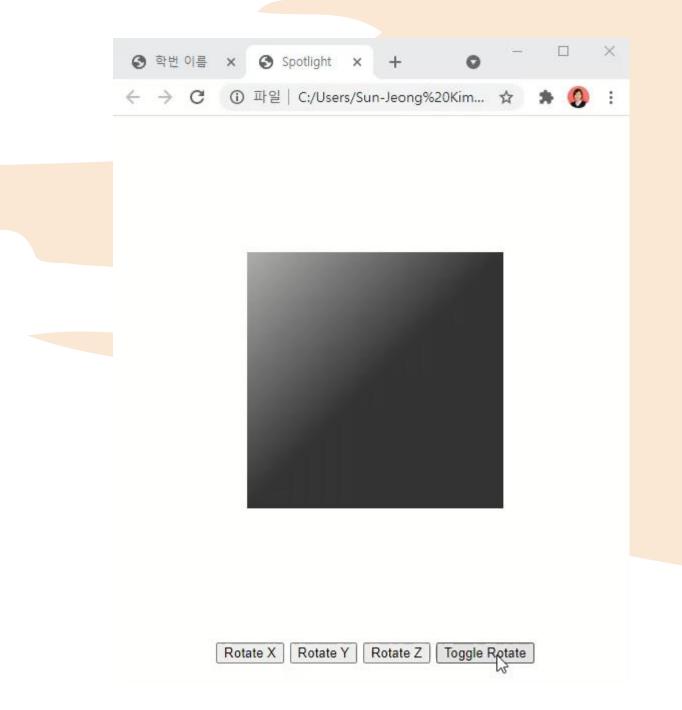
## Spotlight

```
Edit Selection View Go Run Terminal Help
                                                                     spotlight.html - Visual Studio Code
      light.html
                      JS light.js
                                       spotlight.html X JS spotlight.js
      C: > Users > Sun-Jeong Kim > Desktop > CG > ↔ spotlight.html > ↔ html > ↔ head > ↔ script#vertex-shader
             <!DOCTYPE html>
             <html>
                  <head>
مع
                      <title>Spotlight</title>
         4
                      <script id="vertex-shader" type="x-shader/x-vertex">
                      attribute vec4 vPosition;
         6
                      attribute vec4 vNormal;
                      attribute vec4 vColor;
         8
                                                                                                                                                       THE
                      uniform mat4 modelViewMatrix;
         9
       10
                      uniform mat4 projectionMatrix;
                      varying vec4 fColor;
        11
        12
                      uniform vec4 lightPos, lightAmbient, lightDiffuse, lightSpecular;
        13
                      uniform vec3 kAtten, spotDir;
        14
                      uniform float spotExp;
       15
                      uniform vec4 matAmbient, matDiffuse, matSpecular;
       16
                      uniform float matShininess;
       17
       18
                      void main() {
        19
                          gl_Position = projectionMatrix * modelViewMatrix * vPosition;
        20
                          //fColor = vColor;
        21
                          vec4 ambient = lightAmbient * matAmbient;
        22
        23
```

```
<u>File Edit Selection View Go Run Terminal Help</u>
                                                                       spotlight.html - Visual Studio Code
                                                                                                                                                                 □ …
       light.html
                       JS light.is
                                        spotlight.html × JS spotlight.js
       C: > Users > Sun-Jeong Kim > Desktop > CG > ♦ spotlight.html > ♦ html > ♦ head > ♦ script#vertex-shader
Q
        23
        24
                           vec3 N = normalize((modelViewMatrix * vNormal).xyz);
        25
                           vec3 pos = (modelViewMatrix * vPosition).xyz;
مړ
                           vec3 light = lightPos.xyz - pos;
        26
                           float d = length(light);
         27
         28
                           float atten = 1.0 / (kAtten[0] + kAtten[1]*d + kAtten[2]*d*d);
ďg.
                                                                                                                                                         29
                           vec3 L = normalize(light);
                                                                                                                                                         No. of Concession, Name of Street, or other
                                                                                                                                                         THE
                           float kd = max(dot(L, N), 0.0);
         30
                           vec4 diffuse = kd * lightDiffuse * matDiffuse;
         31
出
         32
                           vec3 V = normalize(-pos);
         33
                           vec3 H = normalize(L + V);
         34
                           float ks = pow(max(dot(N, H), 0.0), matShininess);
         35
        36
                           vec4 specular = ks * lightSpecular * matSpecular;
         37
                           if (dot(L, N) < 0.0) specular = vec4(0.0, 0.0, 0.0, 1.0);
         38
         39
                           float spotDot = max(dot(normalize(spotDir), -L), 0.0);
         40
                           if (spotDot > 0.0)
         41
                               atten *= pow(spotDot, spotExp);
         42
                           else
         43
                               atten = 0.0;
         44
         45
                           fColor = ambient + atten * (diffuse + specular);
         46
                           fColor.a = 1.0;
         47
         48
                       </script>
         49
         50
(8)
                       <script id="fragment-shader" type="x-shader/x-fragment">
         51
        52
                       precision mediump float;
        53
                       varying vec4 fColor;
£
        54
                       void main()
         55
⊗ 0 ∆ 0
                                                                                                                Ln 15, Col 30 (7 selected) Spaces: 4 UTF-8 CRLF HTML 🔊 🚨
```

```
<u>File Edit Selection View Go Run Terminal Help</u>
                                                                       spotlight.html - Visual Studio Code
                                                                                                                                                                   □ …
       light.html
                       JS light.js
                                        spotlight.html ×
                                                            JS spotlight.js
       C: > Users > Sun-Jeong Kim > Desktop > CG > ♦ spotlight.html > ♦ html > ♦ head > ♦ script#vertex-shader
        50
        51
                       <script id="fragment-shader" type="x-shader/x-fragment">
                       precision mediump float;
        52
مع
                       varying vec4 fColor;
        53
        54
        55
                       void main() {
ďg.
        56
                           gl FragColor = fColor;
                                                                                                                                                          No. of Concession, Name of Street, or other
        57
                                                                                                                                                          ) MINIE
        58
                       </script>
留
        59
        60
                       <script type="text/javascript" src="Common/webgl-utils.js"></script>
                       <script type="text/javascript" src="Common/initShaders.js"></script>
        61
                       <script type="text/javascript" src="Common/MV.js"></script>
        62
                       <script type="text/javascript" src="trackball.js"></script>
        63
                       <script type="text/javascript" src="spotlight.js"></script>
        64
                  </head>
        65
                  <body>
        66
                       <canvas id="gl-canvas" width="512" height="512">
        67
                           Oops... your browser doesn't support the HTML5 canvas element!
        68
         69
                       </canvas>
        70
                       <div style="width: 512px; text-align: center;">
                           <button id="xButton">Rotate X</button>
        71
        72
                           <button id="yButton">Rotate Y</button>
        73
                           <button id="zButton">Rotate Z</button>
        74
                           <button id="buttonT">Toggle Rotate</button>
        75
                       </div>
        76
                  </body>
        77
              </html>
(8)
€%3
```

```
<u>File Edit Selection View Go Run Terminal Help</u>
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     spotlight.js - Visual Studio Code
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    П ...
                                          ◇ light.html
                                                                                                                                                 JS light.is
                                                                                                                                                                                                                                                        spotlight.html
                                                                                                                                                                                                                                                                                                                                                                                JS spotlight.js X
                                           C: > Users > Sun-Jeong Kim > Desktop > CG > JS spotlight.js > ♦ setLighting > [♠] spotExpLoc
    Q
                                                148
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         Billion
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           149
                                                                                         function setLighting(program) {
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       E MANAGEMENT OF THE PARTY OF TH
                                                                                                                  var lightPos = [-1.0, 1.0, 0.0, 1.0];
                                                150
   مع
                                                                                                                   var lightAmbient = [0.2, 0.2, 0.2, 1.0];
                                                151
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              Total Street Company of the last
                                                                                                                   var lightDiffuse = [1.0, 1.0, 1.0, 1.0];
                                                152
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             William or or or
                                                153
                                                                                                                   var lightSpecular = [1.0, 1.0, 1.0, 1.0];
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            A STATE OF THE PARTY OF THE PAR
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            Supplementary
å
                                               154
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             (MAY 2 May .....
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             PROVINCE:
                                                155
                                                                                                                   var matAmbient = [1.0, 1.0, 1.0, 1.0];
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             THE RESERVE OF THE PERSON NAMED OF THE PERSON 
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             AND DESCRIPTION OF THE
                                               156
                                                                                                                   var matDiffuse = [1.0, 1.0, 1.0, 1.0];
留
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            CONTRACTOR STREET, STR
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            AND ASSESSMENT OF THE PERSON.
                                                                                                                   var matSpecular = [1.0, 1.0, 1.0, 1.0];
                                                157
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            PROFESSION OF STREET
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             WE SHOW IN THE CO.
                                                                                                                   var matShininess = 20.0;
                                                158
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               "Assurement of the second of
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              DECEMBER OF ....
                                                159
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             AND DESCRIPTION OF THE PARTY OF
                                                                                                                    var lightPosLoc = gl.getUniformLocation(program, "lightPos");
                                                160
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              The state of the s
                                                                                                                   gl.uniform4fv(lightPosLoc, lightPos);
                                                161
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           Park Inches
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            var attenLoc = gl.getUniformLocation(program, "kAtten");
                                                162
                                                163
                                                                                                                   gl.uniform3f(attenLoc, 0.0, 0.0, 1.0);
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            THE WOOD
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            BELLIKK KIK
                                                                                                                   var spotDirLoc = gl.getUniformLocation(program, "spotDir");
                                                164
                                                                                                                   gl.uniform3f(spotDirLoc, 0.0, -1.0, -1.0);
                                                165
                                                                                                                   var spotExpLoc = gl.getUniformLocation(program, "spotExp");
                                                166
                                                167
                                                                                                                   gl.uniform1f(spotExpLoc, 5.0);
                                                168
                                                                                                                   var lightAmbientLoc = gl.getUniformLocation(program, "lightAmbient");
                                                169
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               gl.uniform4fv(lightAmbientLoc, lightAmbient);
                                                170
                                                                                                                   var lightDiffuseLoc = gl.getUniformLocation(program, "lightDiffuse");
                                                171
                                                                                                                   gl.uniform4fv(lightDiffuseLoc, lightDiffuse);
                                                172
                                                                                                                   var lightSpecularLoc = gl.getUniformLocation(program, "lightSpecular");
                                                173
                                               174
                                                                                                                   gl.uniform4fv(lightSpecularLoc, lightSpecular);
                                               175
                                                                                                                    var matAmbientLoc = gl.getUniformLocation(program, "matAmbient");
                                                176
                                                                                                                   gl.uniform4fv(matAmbientLoc, matAmbient);
                                                177
                                                                                                                   var matDiffuseLoc = gl.getUniformLocation(program, "matDiffuse");
                                                178
€$3
                                               179
                                                                                                                   gl.uniform4fv(matDiffuseLoc, matDiffuse);
                                                                                                                  var matSpecularLoc = gl.getUniformLocation(program, "matSpecular");
                                               180
   ⊗ 0 ∆ 0
```



## 연습 문제 (3)

- light.js에 있는 setLighting() 함수에서,
  - spotDir의 값을 변경하면, 결과가 어떻게 바뀌는지 설명하시오.
    - 예) gl.uniform3f(spotDirLoc, 0.0, 0.0, -1.0);
  - spotExp의 값을 변경하면, 결과가 어떻게 바뀌는지 설명하시오.
    - 예) gl.uniform1f(spotExpLoc, 10.0);

#### **Moving Light Sources**

- Light sources are geometric objects whose positions or directions are affected by the model-view matrix
- Depending on where we place the position (direction) setting function, we can
  - Move the light source(s) with object(s)
  - Fix the object(s) and move the light source(s)
  - Fix the light source(s) and move the object(s)
  - Move the light source(s) and object(s) independently

File Edit Selection View Go Run Terminal Help light.js - Visual Studio Code □ … light.html JS light.is spotlight.html JS spotlight.js C: > Users > Sun-Jeong Kim > Desktop > CG > JS light.js > [∅] lightPosLoc var gl; 80044 THE PARTY OF THE P var points = []; var colors = []; مع var normals = []; FELTER CO. The second line to the second The same of the sa var axis = 0; STATE OF STREET ďg. var theta = [0, 0, 0];Manager Colors (M) 245-.... var rotation = false; AND VALUE OF THE PARTY. 9 AND DESCRIPTION OF THE 留 (AND DESCRIPTION OF THE PARTY O 10 var viewMatrix, projectionMatrix; All Street, 19th Street The Real Property lies 11 var modelViewMatrixLoc, projectionMatrixLoc; WE Service was an an an AND DESCRIPTION OF THE PARTY OF const eye = vec3(0.0, 0.0, 1.0); 12 DECEMBER OF THE PARTY OF THE PA PERSONAL PROPERTY OF THE PERSONS ASSESSED. AND DESCRIPTION OF THE PARTY OF const at = vec3(0.0, 0.0, 0.0); 13 14 const up = vec3(0.0, 1.0, 0.0); Total Control of the last 15 var trballMatrix = mat4(1, 0, 0, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 1); 16 var numVertCubeTri; 17 BELVE SKILL 18 var lightPos = [-1.0, 1.0, 0.0, 1.0]; 19 var lightPosLoc; 20 m 21 window.onload = function init() 23 var canvas = document.getElementById("gl-canvas"); 24 25 26 gl = WebGLUtils.setupWebGL(canvas); if( !gl ) { 27 alert("WebGL isn't available!"); 28 (8) 29 30 generateColorCube(); 31 £ 32 33 // virtual trackball ⊗ 0 ∆ 0 ⊗ Ln 20, Col 16 (11 selected) Spaces: 4 UTF-8 CRLF JavaScript 8

File Edit Selection View Go Run Terminal Help light.js - Visual Studio Code П ... ◇ light.html JS light.js spotlight.html JS spotlight.js C: > Users > Sun-Jeong Kim > Desktop > CG > JS light.js > [∅] lightPosLoc Q 156 Billion function setLighting(program) { 157 STATE OF STREET //var lightPos = [-1.0, 1.0, 0.0, 1.0]; 158 مع 159 var lightAmbient = [0.2, 0.2, 0.2, 1.0]; The second second The second section in the second var lightDiffuse = [1.0, 1.0, 1.0, 1.0]; The same of the sa 160 161 var lightSpecular = [1.0, 1.0, 1.0, 1.0]; STATE OF STREET å Mary and the same of the same 162 (MAY 245 ..... var matAmbient = [1.0, 1.0, 1.0, 1.0];163 PROPERTY OF STREET var matDiffuse = [1.0, 1.0, 1.0, 1.0]; 164 A STATE OF THE REAL PROPERTY. 留 Marie Inc. var matSpecular = [1.0, 1.0, 1.0, 1.0]; 165 All Street, 19th Street The Real Property lies WE Serve was --var matShininess = 100.0; 166 ARREST MARKET LINE TO A THE PARK THE LANCOVOR LINE OF L. ... 167 PRODUCE LANGUAGE STORY AND ADDRESS. AND PERSONAL PROPERTY. lightPosLoc = gl.getUniformLocation(program, "lightPos"); 168 Promote de la constante de la //gl.uniform4fv(lightPosLoc, lightPos); 169 Total Control of the last var attenLoc = gl.getUniformLocation(program, "kAtten"); 170 Maria ene ene gl.uniform3f(attenLoc, 0.0, 0.0, 1.0); 171 172 var lightAmbientLoc = gl.getUniformLocation(program, "lightAmbient"); BELVER AND gl.uniform4fv(lightAmbientLoc, lightAmbient); 173 var lightDiffuseLoc = gl.getUniformLocation(program, "lightDiffuse"); 174 gl.uniform4fv(lightDiffuseLoc, lightDiffuse); 175 m var lightSpecularLoc = gl.getUniformLocation(program, "lightSpecular"); 176 gl.uniform4fv(lightSpecularLoc, lightSpecular); 177 178 179 var matAmbientLoc = gl.getUniformLocation(program, "matAmbient"); gl.uniform4fv(matAmbientLoc, matAmbient); 180 var matDiffuseLoc = gl.getUniformLocation(program, "matDiffuse"); 181 gl.uniform4fv(matDiffuseLoc, matDiffuse); 182 var matSpecularLoc = gl.getUniformLocation(program, "matSpecular"); 183 gl.uniform4fv(matSpecularLoc, matSpecular); 184 var matShininessLoc = gl.getUniformLocation(program, "matShininess"); 185 186 gl.uniform1f(matShininessLoc, matShininess); €\$3 187 188 ⊗0 10 € Ln 20, Col 16 (11 selected) Spaces: 4 UTF-8 CRLF JavaScript

```
File Edit Selection View Go Run Terminal Help
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              light.js - Visual Studio Code
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               П ...
                                                  ◇ light.html
                                                                                                                                                                         JS light.js
                                                                                                                                                                                                                                                                                              spotlight.html
                                                                                                                                                                                                                                                                                                                                                                                                                                         JS spotlight.js
                                                    C: > Users > Sun-Jeong Kim > Desktop > CG > JS light.js > [∅] lightPosLoc
                                                        129
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          Billion
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    CONTRACTOR OF THE PROPERTY OF 
                                                        130
                                                                                                                                      setLighting(program);
                                                        131
     مړ
                                                        132
                                                                                                                                       render();
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               The second second
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                The second section in the second
                                                        133
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                The same of the same of
                                                       134
4
                                                                                                       function render() {
                                                        135
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               Mary and the same of the same 
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                267216 .....
                                                                                                                                     gl.clear(gl.COLOR_BUFFER_BIT | gl.DEPTH_BUFFER_BIT);
                                                        136
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                AND VALUE OF STREET
                                                       137
 留
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               P. St. Bernand, C. P. St. Co.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                AND WEST STREET, STREE
                                                                                                                                      if( rotation ) theta[axis] += 2.0;
                                                        138
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 All Million Child Co.
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                The State of the S
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  WE Service was ......
                                                                                                                                      var rx = rotateX(theta[0]);
                                                        139
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  AND DESCRIPTION OF THE PARTY OF
                                                                                                                                     var ry = rotateY(theta[1]);
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                lagavatur er ....
                                                        140
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                PRODUCE LANGUAGE STREET, SHORE
                                                        141
                                                                                                                                      var rz = rotateZ(theta[2]);
                                                                                                                                      var lightMatrix = mult(ry, rx);
                                                        142
                                                                                                                                      lightMatrix = mult(rz, lightMatrix);
                                                        143
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              Maria ene ene
                                                        144
                                                                                                                                      var newX = lightMatrix[0][0]*lightPos[0] + lightMatrix[1][0]*lightPos[1] + lightMatrix[2][0]*lightPos[2];
                                                                                                                                       var newY = lightMatrix[0][1]*lightPos[0] + lightMatrix[1][1]*lightPos[1] + lightMatrix[2][1]*lightPos[2];
                                                        145
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                BELVER AND
                                                                                                                                      var newZ = lightMatrix[0][2]*lightPos[0] + lightMatrix[1][2]*lightPos[1] + lightMatrix[2][2]*lightPos[2];
                                                        146
                                                                                                                                      gl.uniform4f(lightPosLoc, newX, newY, newZ, 1.0);
                                                        147
                                                       148
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            modelViewMatrix = mult(viewMatrix, trballMatrix);
                                                       149
                                                                                                                                      gl.uniformMatrix4fv(modelViewMatrixLoc, false, flatten(modelViewMatrix));
                                                        150
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                151
                                                                                                                                      gl.drawArrays(gl.TRIANGLES, 0, points.length);
                                                        152
                                                       153
                                                       154
                                                                                                                                      window.requestAnimationFrame(render);
                                                        155
                                                      156
  (8)
                                                       157
                                                                                                       function setLighting(program) {
                                                                                                                                     //var lightPos = [-1.0, 1.0, 0.0, 1.0];
                                                        158
                                                                                                                                     var lightAmbient = [0.2, 0.2, 0.2, 1.0];
                                                        159
£
                                                                                                                                      var lightDiffuse = [1.0, 1.0, 1.0, 1.0];
                                                       160
                                                                                                                                     var lightSpecular = [1.0, 1.0, 1.0, 1.0];
                                                        161
     ⊗ 0 ∆ 0 ⊗
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       Ln 20, Col 16 (11 selected) Spaces: 4 UTF-8 CRLF JavaScript
```

