# ICG 2021 Spring Homework1 Guidance 2021/03/18

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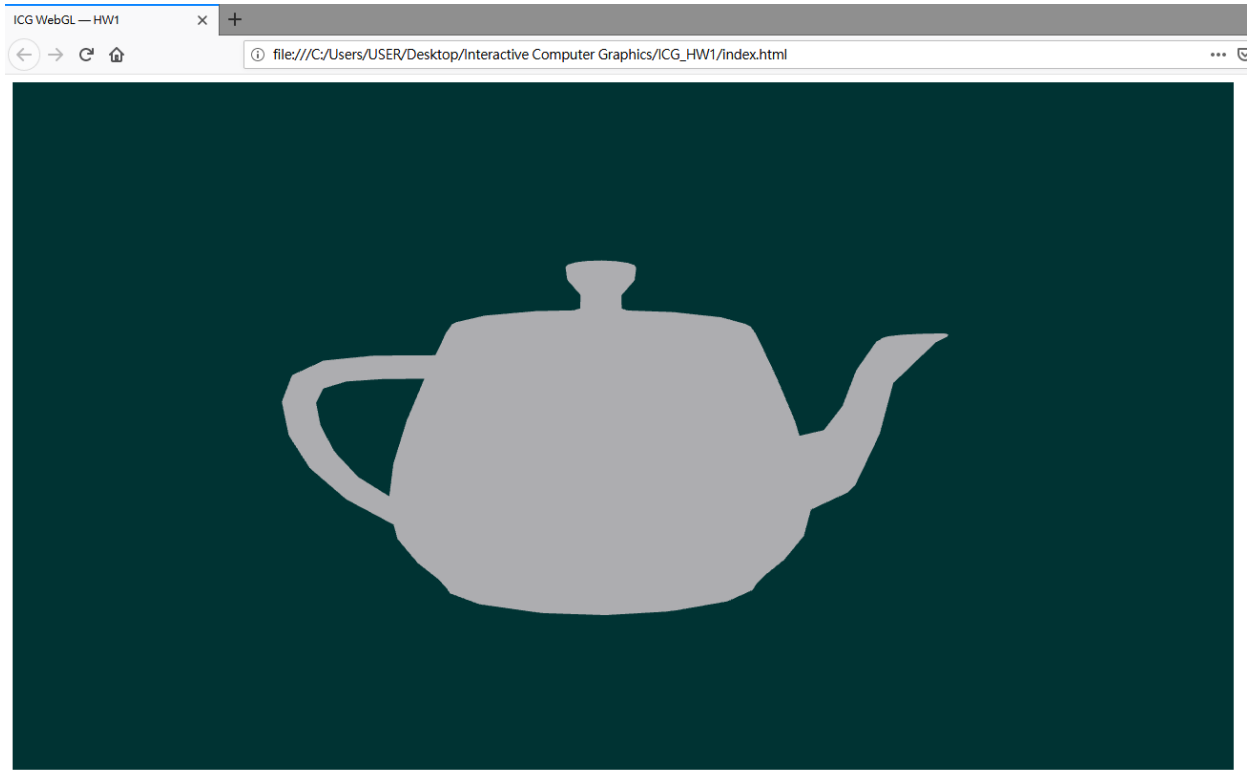
# Environment Setup

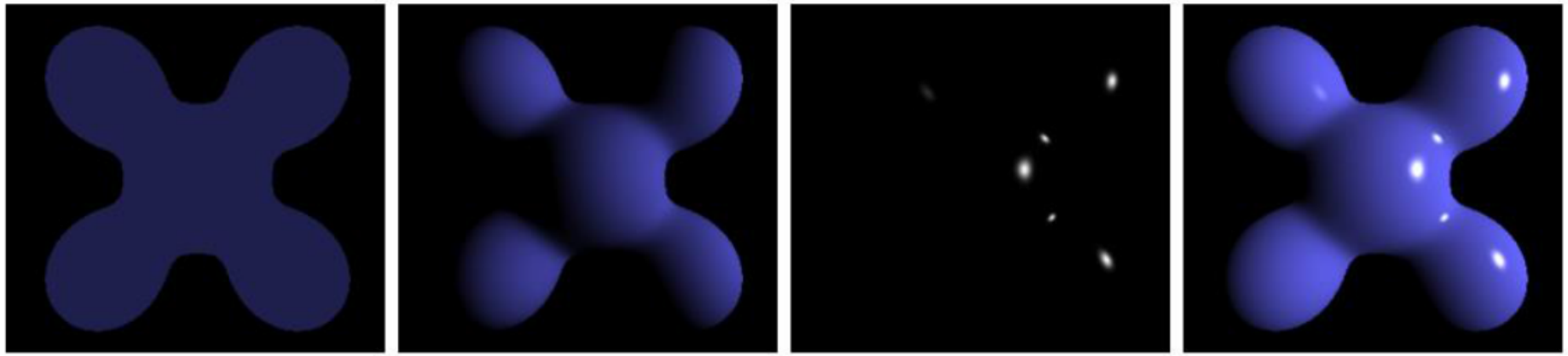
- Download sample code from course website
- Follow steps in **HW1_Guide.pdf** file



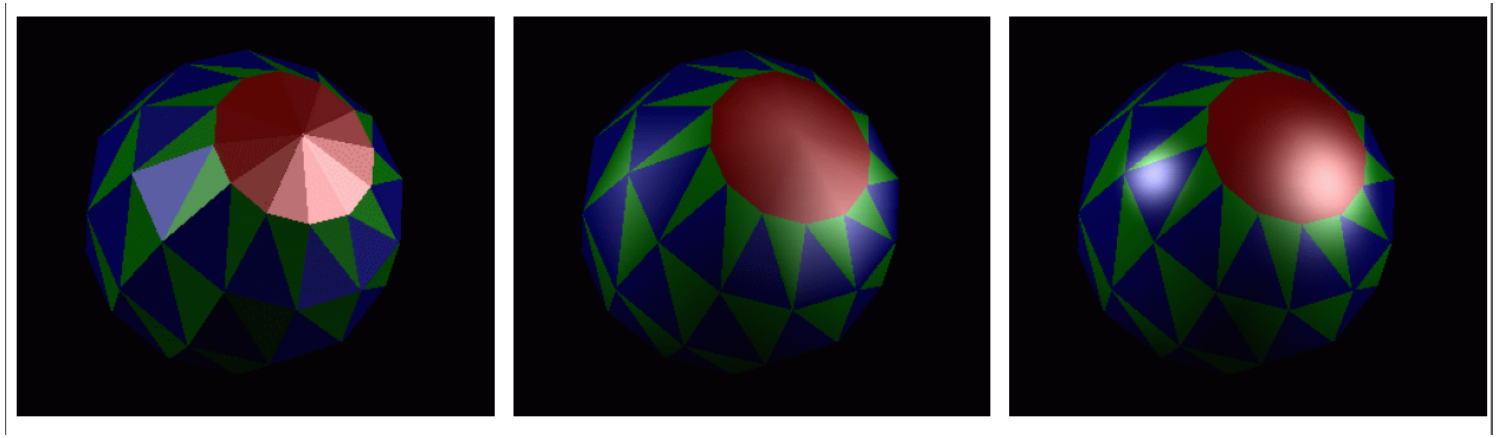
# Requirements (Due to 2021/05/13)

- Implement **Flat, Gouraud, and Phong shading with Phong reflection model** in shaders.
- **Enable multiple transformations (four fundamental transformations) on objects in a scene**. You are free to use those provided model files and arrange them to form the scene on your own style.
- At least **3 objects** & at least **3 light sources**
- Bonus: Special effects on shading / lighting / animation, …

# Phong Reflection Model

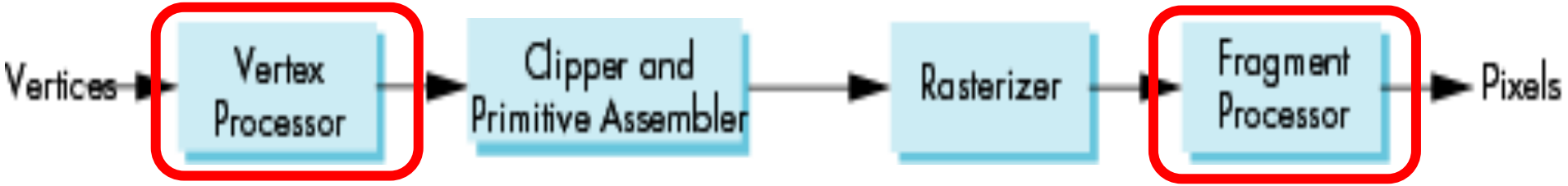


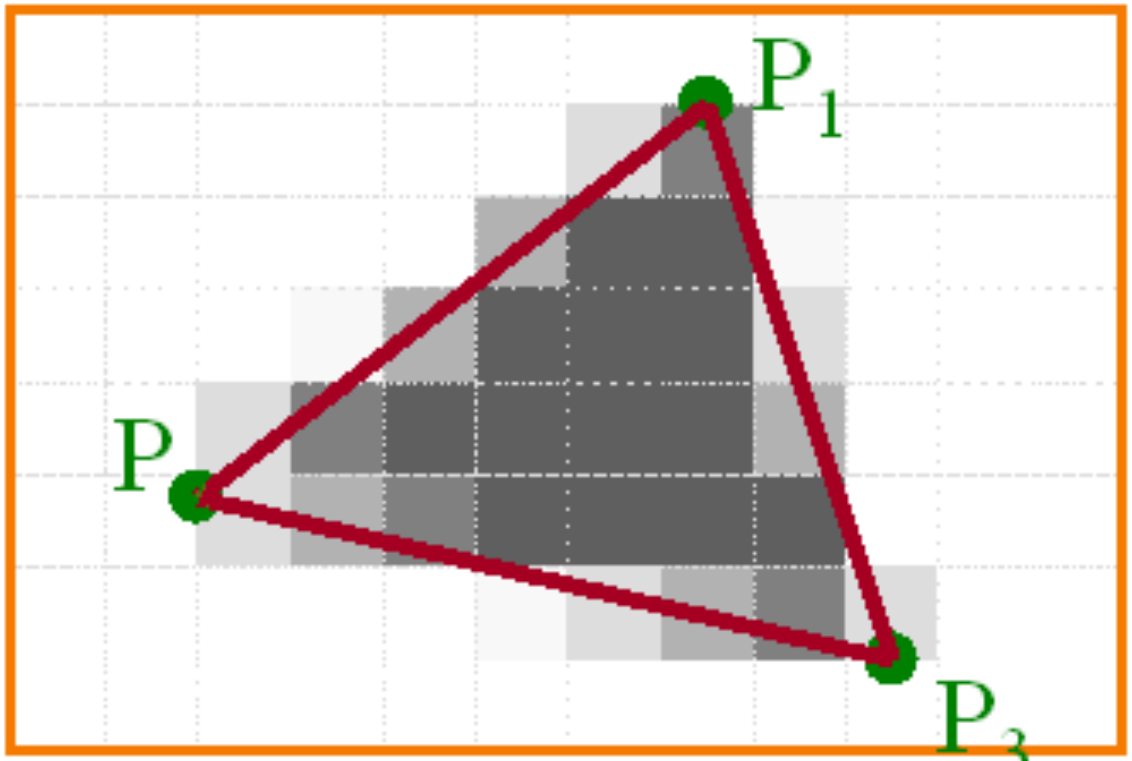
# Shading



- Flat Shading: Constant normal on the whole surface
- Gouraud Shading: Different vertex normal, interpolated vertex color on a fragment
- Phong Shading: Different vertex normal, interpolated vertex normal on a fragment

# Rendering Pipeline



# Graphics API & Shader Language

| Graphics API | Shader Language |
| --- | --- |
| OpenGL / WebGL | GLSL (OpenGL Shading Language) |
| DirectX | HLSL (High Level Shading Language) |
| Vulkan | SPIR-V |

# Shader (GLSL)

```
15  <script id="fragmentShader" type="fragment">
16      precision mediump float;
17
18      varying vec4 fragcolor;
19
20      void main(void) {
21          gl_FragColor = fragcolor;
22      }
23  </script>
```

```
35  <script id="vertexShader" type="vertex">
36      attribute vec3 aVertexPosition;
37      attribute vec3 aFrontColor;
38
39      uniform mat4 uMVMatrix;
40      uniform mat4 uPMatrix;
41
42      varying vec4 fragcolor;
43
44      void main(void) {
45          fragcolor = vec4(aFrontColor.rgb, 1.0);
46          gl_Position = uPMatrix * uMVMatrix * vec4(aVertexPosition, 1.0);
47      }
48  </script>
```

# Shader Data (1/2)

```
15  <script id="fragmentShader" type="fragment">
16      precision mediump float;
17
18      varying vec4 fragcolor;
19
20      void main(void) {
21          gl_FragColor = fragcolor;
22      }
23  </script>
```

```
35  <script id="vertexShader" type="vertex">
36      attribute vec3 aVertexPosition;
37      attribute vec3 aFrontColor;
38
39      uniform mat4 uMVMatrix;
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42      varying vec4 fragcolor;
43
44      void main(void) {
45          fragcolor = vec4(aFrontColor.rgb, 1.0);
46          gl_Position = uPMatrix * uMVMatrix * vec4(aVertexPosition, 1.0);
47      }
48  </script>
```

# Shader Data (2/2)

**SHADER DATA**

"Per-object constant"

**Uniform**
**= Shared Constant**

**Vertex Data**
**= ANYTHING YOU WANT!**

**Example?**
**Positions…**
**Normals…**
**Colors…**
**Texture Coordinates…**

# Load Models

- 已經將大部分課程網的 tri 模型轉成 json 檔

Example　Csie.json

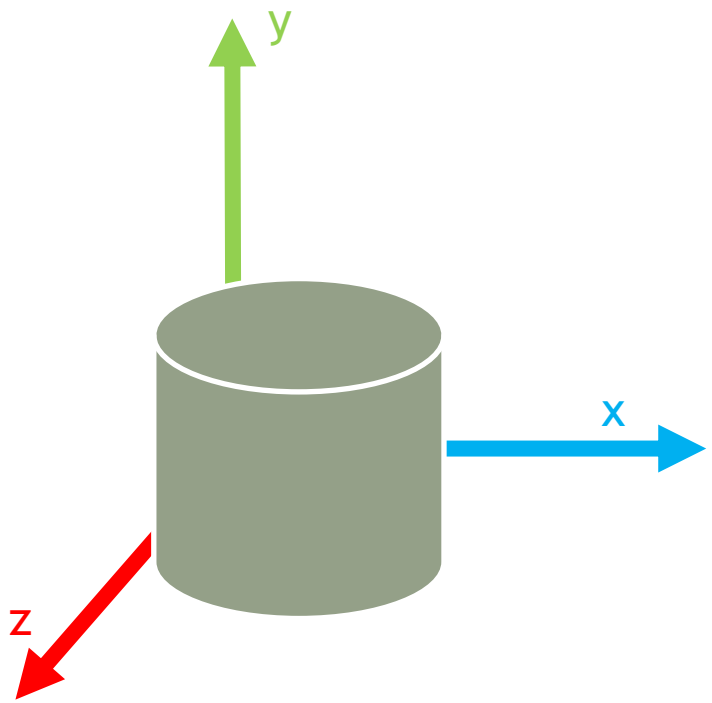
```
{
    "vertexPositions" : [0.85,0.6471428571428571,0.0571428
    "vertexNormals" : [0.000000,1.000000,0.000000,0.000000
    "vertexFrontcolors" : [1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0
    "vertexBackcolors" : [0.9803921568627451,0.0,0.0,0.980
}
```

# Load Models

- 將範例code的茶壺路徑替換成其他想要的模型即可。

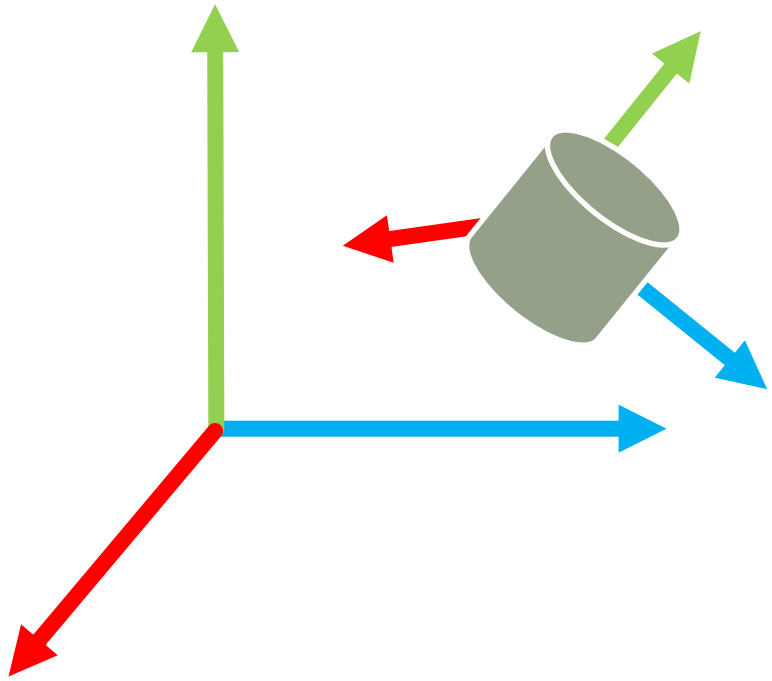
```
170     function loadTeapot() {
171         var request = new XMLHttpRequest();
172         request.open("GET", "./model/Teapot.json");
173         request.onreadystatechange = function () {
174             if (request.readyState == 4) {
175                 handleLoadedTeapot(JSON.parse(request.responseText));
176             }
177         }
178         request.send();
179     }
```

# World transform




Model coordinates

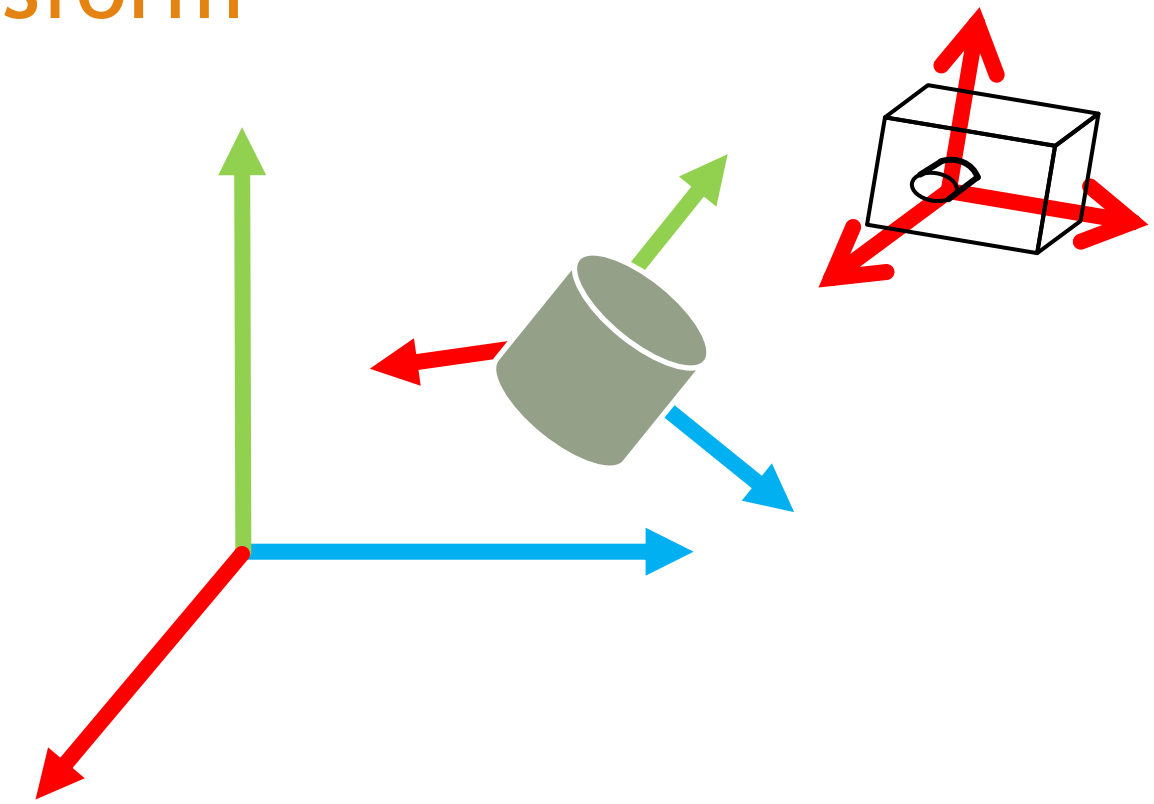
# World transform



World coordinates

```
gl_Position = uPMatrix * uMVMatrix * vec4(aVertexPosition, 1.0);
```

# World transform



Camera coordinates

```
gl_Position = uPMatrix * uMVMatrix * vec4(aVertexPosition, 1.0);
```

# Transformations

- Fundamental Transformations:
  - Translation、Scale、Rotation、Shear
  - Order of matrix multiplication may affect final result

- Homogeneous Coordinates

**Matrix x Vertex (in this order !!) = TransformedVertex**

$$\begin{bmatrix} a & b & c & d \\ e & f & g & h \\ i & j & k & l \\ m & n & o & p \end{bmatrix} \times \begin{bmatrix} x \\ y \\ z \\ w \end{bmatrix} = \begin{bmatrix} ax + by + cz + dw \\ ex + fy + gz + hw \\ ix + jy + kz + lw \\ mx + ny + oz + pw \end{bmatrix}$$

# Translation

These are the most simple tranformation matrices to understand. A translation matrix look like this :

$$\begin{bmatrix} 1 & 0 & 0 & X \\ 0 & 1 & 0 & Y \\ 0 & 0 & 1 & Z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

where X,Y,Z are the values that you want to add to your position.

So if we want to translate the vector (10,10,10,1) of 10 units in the X direction, we get :

$$\begin{bmatrix} 1 & 0 & 0 & 10 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} * \begin{bmatrix} 10 \\ 10 \\ 10 \\ 1 \end{bmatrix} = \begin{bmatrix} 1*10+0*10+0*10+10*1 \\ 0*10+1*10+0*10+0*1 \\ 0*10+0*10+1*10+0*1 \\ 0*10+0*10+0*10+1*1 \end{bmatrix} = \begin{bmatrix} 10+0+0+10 \\ 0+10+0+0 \\ 0+0+10+0 \\ 0+0+0+1 \end{bmatrix} = \begin{bmatrix} 20 \\ 10 \\ 10 \\ 1 \end{bmatrix}$$

```
200         // Setup Model-View Matrix
201         mat4.identity(mvMatrix);
202         mat4.translate(mvMatrix, [0, 0, -40]);
203         mat4.rotate(mvMatrix, degToRad(teapotAngle), [0, 1, 0]);
```

# Scale

$$\begin{bmatrix} x & 0 & 0 & 0 \\ 0 & y & 0 & 0 \\ 0 & 0 & z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

So if you want to scale a vector (position or direction, it doesn't matter) by 2.0 in all directions :

$$\begin{bmatrix} 2 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} x \\ y \\ z \\ w \end{bmatrix} = \begin{bmatrix} 2*x+0*y+0*z+0*w \\ 0*x+2*y+0*z+0*w \\ 0*x+0*y+2*z+0*w \\ 0*x+0*y+0*z+1*w \end{bmatrix} = \begin{bmatrix} 2*x+0+0+0 \\ 0+2*y+0+0 \\ 0+0+2*z+0 \\ 0+0+0+1*w \end{bmatrix} = \begin{bmatrix} 2*x \\ 2*y \\ 2*z \\ w \end{bmatrix}$$

# Rotate

$$R_x(\theta) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix}$$

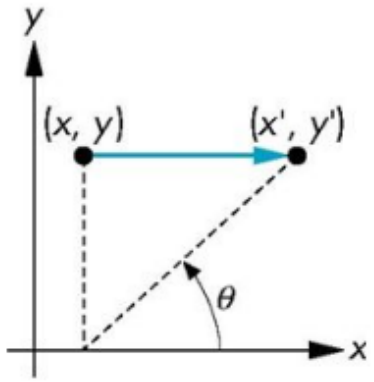
$$R_y(\theta) = \begin{bmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{bmatrix}$$

$$R_z(\theta) = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

# Shear

Consider simple shear along $x$ axis

$$x' = x + y \cot \theta$$
$$y' = y$$
$$z' = z$$




$$\mathbf{H}(\theta) = \begin{bmatrix} 1 & \cot\theta & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

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- Bonus: Special effects on shading / lighting / animation, …

# Result Example

# Reference

- https://webglfundamentals.org/
- http://learningwebgl.com/blog/?page_id=1217
- https://learnopengl.com/

# TA Hours

- 聶偲帆 (CSIE R505)
  - r08944017@csie.ntu.edu.tw
  - Thursday 16:00 ~ 17:00
- 李建德 (CSIE R505)
  - r08922180@ntu.edu.tw
  - Thursday 15:00 ~ 16:00
- 陳禹樵 (CSIE R505)
  - sorevan@cmlab.csie.ntu.edu.tw
  - Tuesday 10:00 ~ 11:00

# Q & A