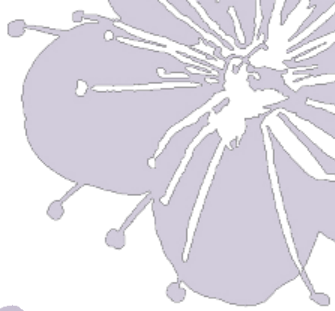
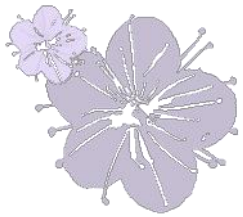
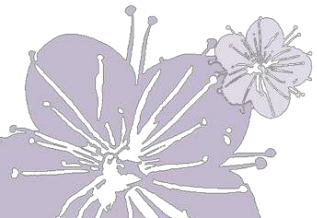


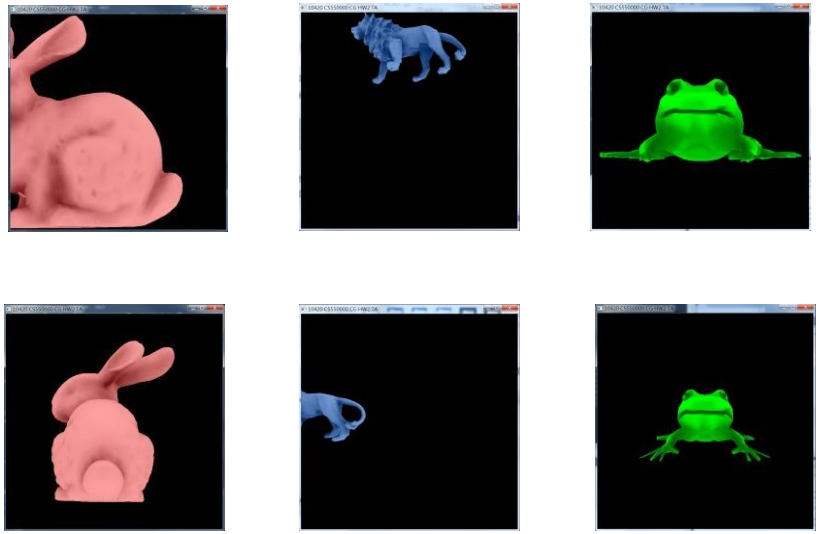

Homework 2

CS 550000 Computer Graphics
CGV Lab, NTHUCS


Goal

- Render and manipulate 3D models by implementing **transformation matrices**.



Goal

- Render and manipulate 3D models by implementing **transformation matrices**.
- Step by step
  1) Geometrical transformation
  2) Viewing transformation
  3) Projection transformation
- Reminders
  - You CANNOT use the existing transform API of OpenGL 1.X.

    e.g. glRotate, glTranslate, glScale

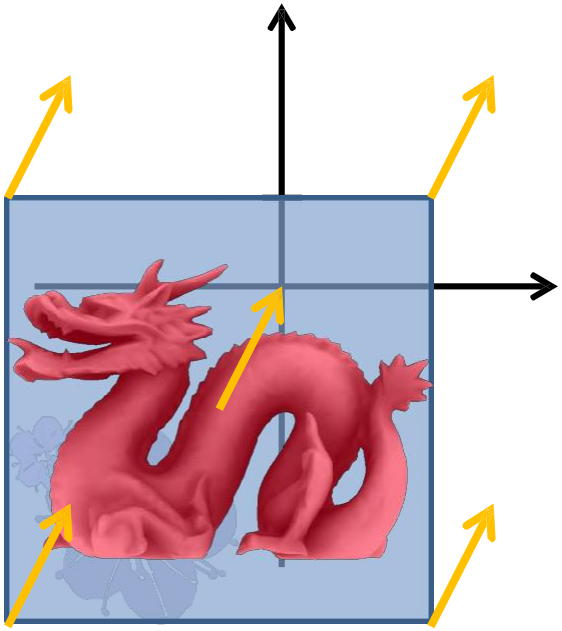
Grading Principle

Total score: 100

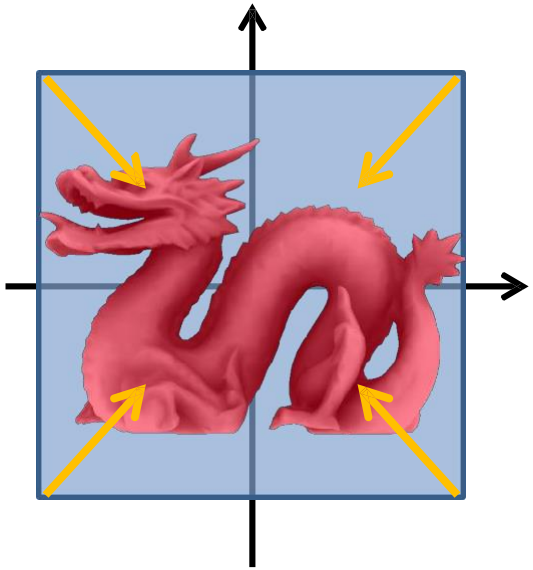
- Transformation(70%)
  - Implement MVP matrices.
    - Geometrical transformation: 30%
    - Viewing transformation : 30%
    - Projection transformation : 10%
- Control (15%)
  - Keyboard & Mouse (Appendix)
- Display (5%)
  - Display information such as model, mode, operation in the console window
- Report (10%)
  - Express your work.
    - How to operate your program
    - Implementation and problems you met
    - Other efforts you have done
    - Screenshots

What we have done in HW1

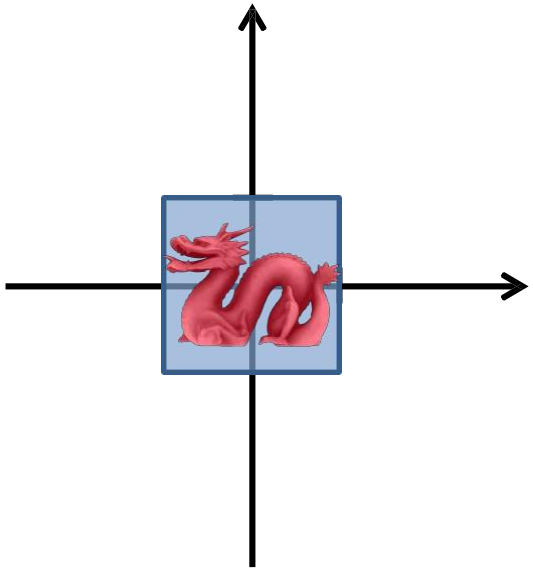
1. Translation



2. Scaling

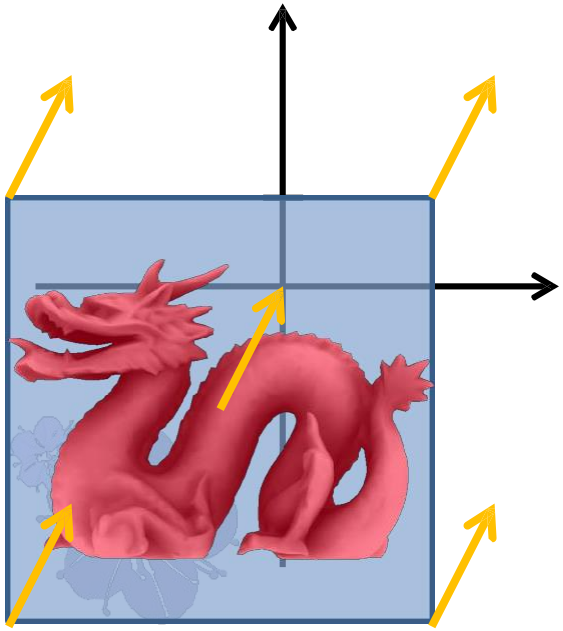


Normalized!

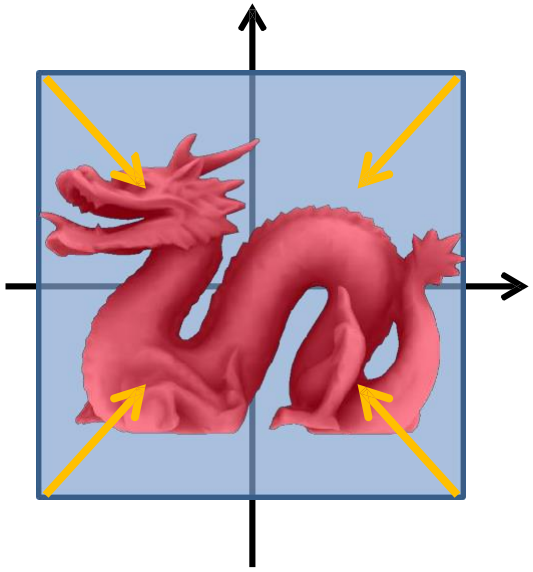


What we will do in HW2

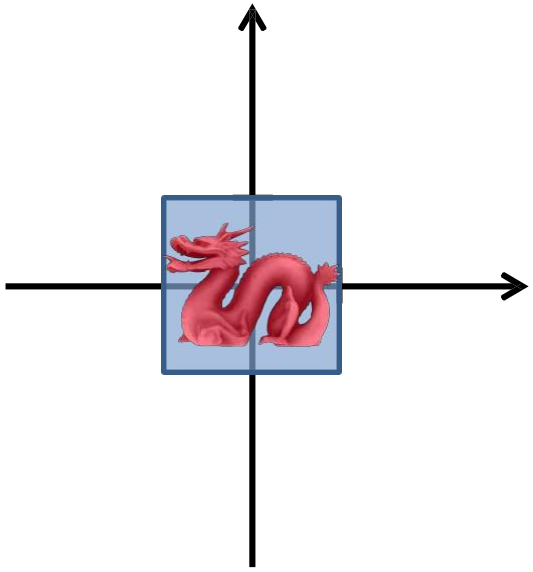
1. Translation



2. Scaling



Normalized!



Use different method to normalize 3D models!

Concept

$$\begin{bmatrix} \square & \square & \square & \square \\ \square & \square & \square & \square \\ \square & \square & \square & \square \\ \square & \square & \square & \square \end{bmatrix} \begin{bmatrix} \square & \square & \square & \square \\ \square & \square & \square & \square \\ \square & \square & \square & \square \\ \square & \square & \square & \square \end{bmatrix} \begin{bmatrix} \square & \square & \square & \square \\ \square & \square & \square & \square \\ \square & \square & \square & \square \\ \square & \square & \square & \square \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = \begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix}$$

Projecting Transformation

Viewing Transformation

Model (Geometrical) Transformation

Coordinates read from .obj

Concept

- Default setting in HW1

$$\underbrace{\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}}_{P} \underbrace{\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}}_{V} \underbrace{\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}}_{M}$$

shader.vert

```
1  attribute vec4 av4position;
2  attribute vec3 av3color;
3
4  varying vec3 vv3color;
5
6  void main() {
7      // NOTE!! column major
8      mat4 mvp = mat4(
9          vec4(    1,    0,    0,    0),
10         vec4(    0,    1,    0,    0),
11         vec4(    0,    0,   -1,    0),
12         vec4(    0,    0,    0,    1)
13     );
14     vv3color = av3color;
15     gl_Position = mvp * av4position;
```

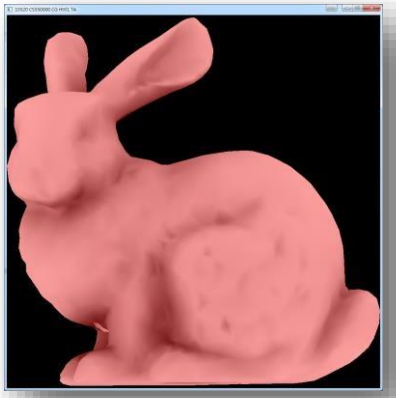
Remember to delete the default setting.
We will implement MVP ourselves in HW2!

Step1: Geometrical Transformation

- Using the **translation** and **scaling** matrices to implement normalization.

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \square & \square & \square & \square \\ \square & \square & \square & \square \\ \square & \square & \square & \square \\ \square & \square & \square & \square \end{bmatrix}$$

P **V** **M**



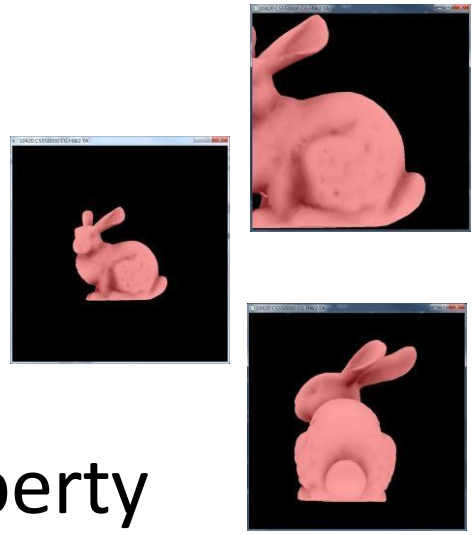
- Reference
  - CG04-Transformation p.39-p.43

Step1: Geometrical Transformation

- Manipulate 3D models
  - Translation, scaling, rotation

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \square & \square & \square & \square \\ \square & \square & \square & \square \\ \square & \square & \square & \square \\ \square & \square & \square & \square \end{bmatrix}$$

P **V** **M**



- Be careful of the commutative property
  - $T \cdot R \neq R \cdot T$

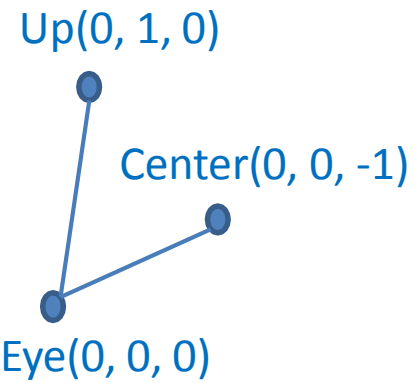
Step2: Viewing Transformation

- Display 3D models from different view.
  - Eye position, center position, up position

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \square & \square & \square & \square \\ \square & \square & \square & \square \\ \square & \square & \square & \square \\ \square & \square & \square & \square \end{bmatrix}$$

P **V** **M**

Default value in HW1



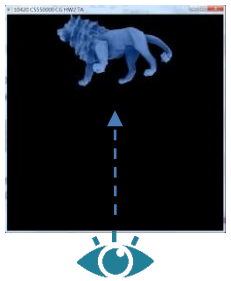
- Reference
  - CG04-Transformation p.72

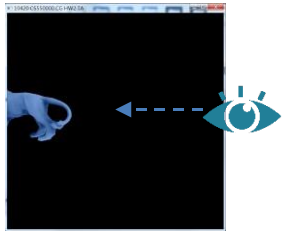
Step2: Viewing Transformation

- Display 3D models from different view.
  - Eye position, center position, up position

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \square & \square & \square & \square \\ \square & \square & \square & \square \\ \square & \square & \square & \square \\ \square & \square & \square & \square \end{bmatrix} \begin{bmatrix} \square & \square & \square & \square \\ \square & \square & \square & \square \\ \square & \square & \square & \square \\ \square & \square & \square & \square \end{bmatrix}$$

P **V** **M**





- Requirement
  - Center position & up position should **not be changed** if we change eye position

Relationship between Eye, Center, Up

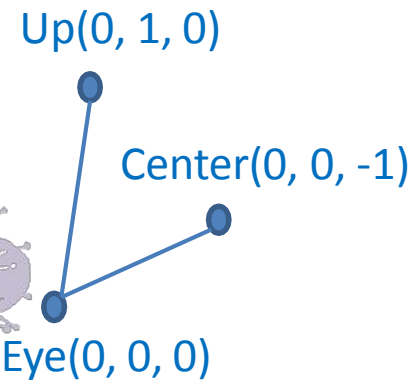
- When change eye(center) position, we have to adjust up position to get a proper result, here is an example, if we move eye from (0,0,0) to (0,3,0)

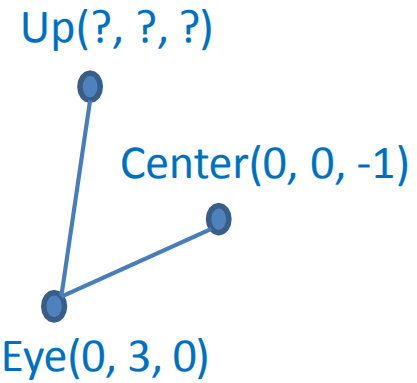
Forward = center(0,0,-1)-eye(0,0,0) = (0,0,-1)

Forward = center(0,0,-1)-eye(0,3,0) = (0,-3,-1)

Relationship between Eye, Center, Up

- Because the forward vector and up vector must be perpendicular, now forward vector changed, we need to compute new up vector



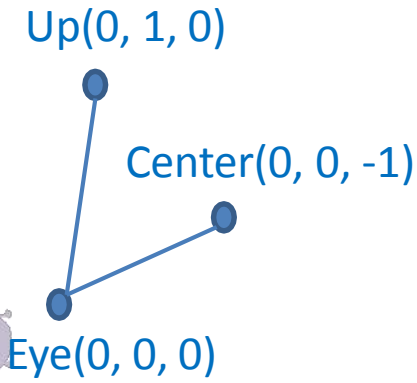


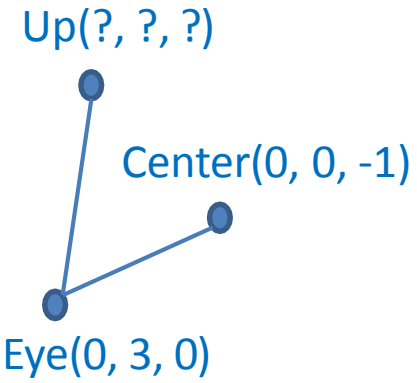
Forward = center(0,0,-1)-eye(0,0,0) = (0,0,-1)

Forward = center(0,0,-1)-eye(0,3,0) = (0,-3,-1)

Relationship between Eye, Center, Up

- In this case, we can compute right vector by the cross product of forward and up vector(old one)





Forward = center(0,0,-1)-eye(0,0,0) = (0,0,-1)

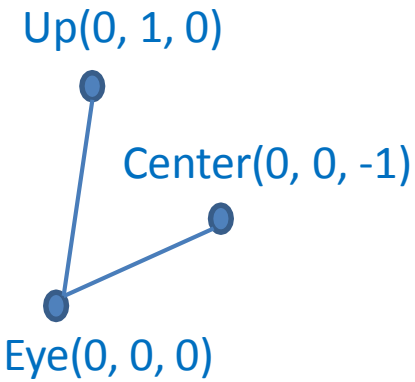
Right = forward(0,0,-1) X up(0,1,0) = (1,0,0)

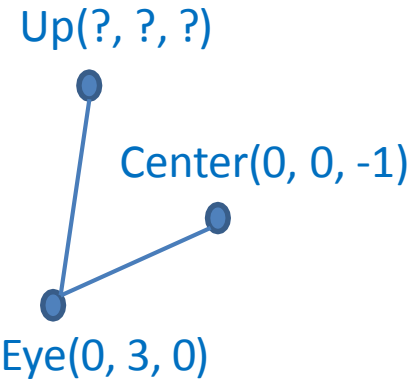
Forward = center(0,0,-1)-eye(0,3,0) = (0,-3,-1)

Right = forward(0,-3,-1) X up(0,1,0) = (1,0,0)

Relationship between Eye, Center, Up

- Finally re-compute new up vector by the cross product of right vector and forward vector, and find new up position!





Forward = center(0,0,-1)-eye(0,0,0) = (0,0,-1)
Right = forward(0,0,-1) X up(0,1,0) = (1,0,0)
Up = right(1,0,0) X forward(0,0,-1) = (0,1,0)

Forward = center(0,0,-1)-eye(0,3,0) = (0,-3,-
Right = forward(0,-3,-1) X up(0,1,0) = (1,0,0)
Up vector(new) =
right(1,0,0) X forward(0,-3,-1) = (0,-1,-3)
Up(position) =
Eye(0,3,0) + up vector(0,-1,-3) =
(0, 2, -3)

Step3: Projection Transformation

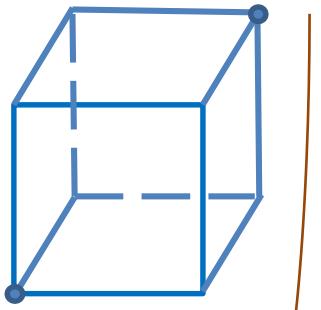
- Project 3D models on screen in different way.
  - Parallel(orthogonal), perspective projection

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \square & \square & \square & \square \\ \square & \square & \square & \square \\ \square & \square & \square & \square \\ \square & \square & \square & \square \end{bmatrix} \begin{bmatrix} \square & \square & \square & \square \\ \square & \square & \square & \square \\ \square & \square & \square & \square \\ \square & \square & \square & \square \end{bmatrix}$$

P **V** **M**

Default value in HW1 (parallel)

(xmax, ymax, zfar) = (1, 1, -1)



(xmin, ymin, znear) = (-1, -1, 1)

Coordinates!

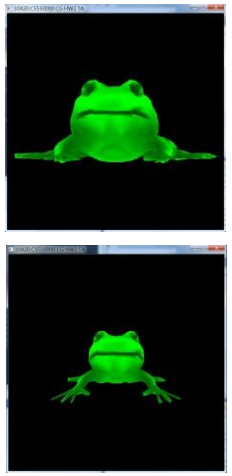
- Reference
  - CG04-Transformation p.121-p.128

Step3: Projection Transformation

- Project 3D models on screen in different way.
  - Parallel(orthogonal), perspective

$$\begin{bmatrix} \square & \square & \square & \square \\ \square & \square & \square & \square \\ \square & \square & \square & \square \\ \square & \square & \square & \square \end{bmatrix} \begin{bmatrix} \square & \square & \square & \square \\ \square & \square & \square & \square \\ \square & \square & \square & \square \\ \square & \square & \square & \square \end{bmatrix} \begin{bmatrix} \square & \square & \square & \square \\ \square & \square & \square & \square \\ \square & \square & \square & \square \\ \square & \square & \square & \square \end{bmatrix}$$

P **V** **M**



- Reminder
  - OpenGL APIs: `znear`, `zfar` are **distances** to the viewpoint instead of the z coordinates.
  - The model should appear on the screen directly. Please find the proper values of all the parameters (e.g. znear, zfar, eye).

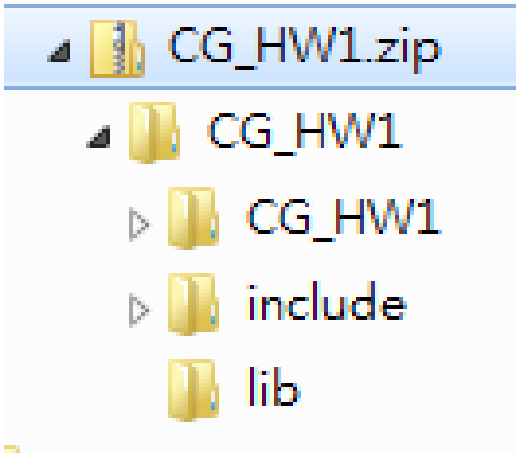
Submission

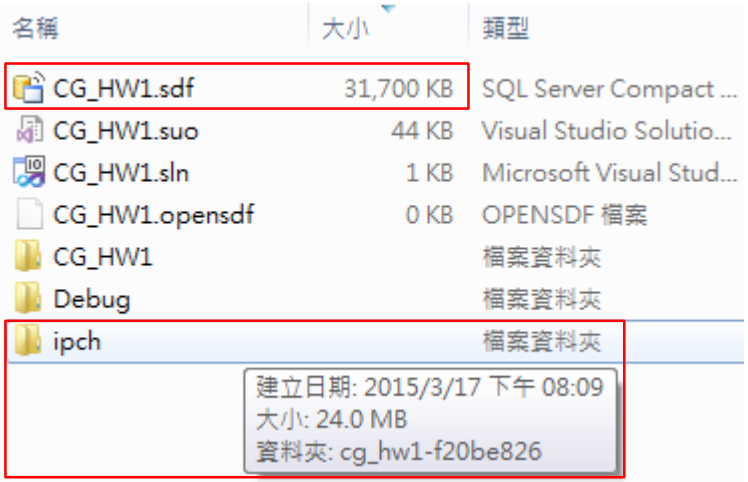
- Due date: April 19th, 2017
- Submit your project to iLMS.
- Filename: HW2_XXXXXXXXX.zip
- Put both “lib” and “include” folder in your zip file

國立清華大學 數位學習系統

位置: 計算機圖學Computer Graphics > 作業 新增 | 複製

項次	標題	分組作業	已評分 / 繳交	期限	動作
1	HW1: Draw Some Geometry Models		0 / 0	04-06 23:59	編輯 | 刪除



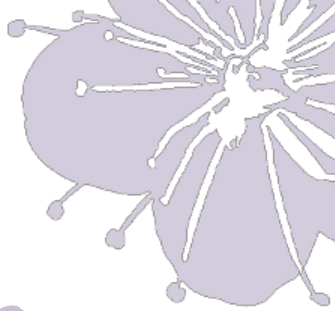


*** Remove “ipch” folder and “.sdf” file. ***

Reminders

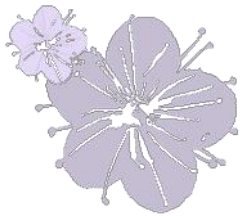
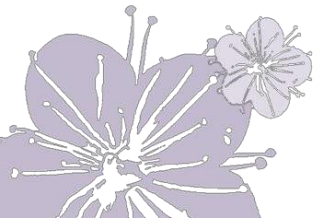
- Late submission is accepted. (-10%/week)
- Ask and share information through iLMS


DEMO




Appendix

CS 550000 Computer Graphics
April 13, 2016
Department of Computer Science
National Tsing Hua University


HW2 Framework

main.cpp

- Global variable

```
28  // Shader attributes
29  GLint iLocPosition;
30  GLint iLocColor;
31  GLint iLocMVP;
```

- void setShaders()

```
245     // link program
246     glLinkProgram(p);
247
248     iLocPosition = glGetAttribLocation (p, "av4position");
249     iLocColor    = glGetAttribLocation (p, "av3color");
250     iLocMVP      = glGetUniformLocation(p, "mvp");
```

- void onDisplay()

```
178     // bind array pointers to shader
179     glVertexAttribPointer(iLocPosition, 3, GL_FLOAT, GL_FALSE, 0, triangle_vertex);
180     glVertexAttribPointer(   iLocColor, 3, GL_FLOAT, GL_FALSE, 0, triangle_color);
181
182     // bind uniform matrix to shader
183     glUniformMatrix4fv(iLocMVP, 1, GL_FALSE, mvp);
```

const GLfloat *

What you need to define in HW2

shader.vert

```
1   attribute vec4 av4position;
2   attribute vec3 av3color;
3
4   varying vec3 vv3color;
5
6   uniform mat4 mvp;
7
8   void main() {
9       // NOTE!! column major
10      /*mat4 mvp = mat4(
11          vec4(    1,    0,    0,    0),
12          vec4(    0,    1,    0,    0),
13          vec4(    0,    0,   -1,    0),
14          vec4(    0,    0,    0,    1)
15      );*/
16      vv3color = av3color;
17      gl_Position = mvp * av4position;
18  }
19
```

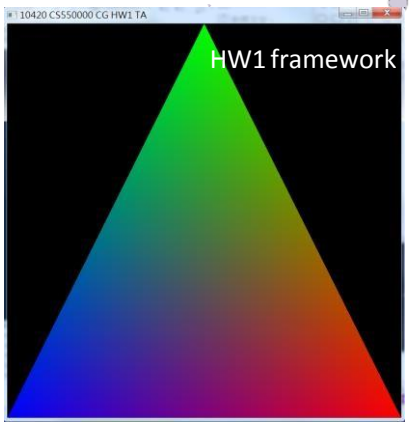
HW2 Framework

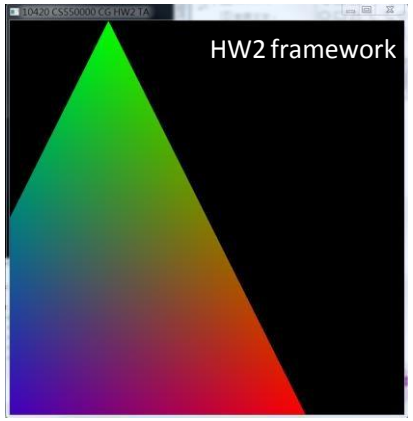
main.cpp

(Global Scope) | onDisplay(void)

```
148     //MVP
149     Matrix4 T;
150     Matrix4 S;
151     Matrix4 R;
152
153     Matrix4 M = Matrix4(
154                         1, 0, 0, -0.5,
155                         0, 1, 0, 0,
156                         0, 0, 1, 0,
157                         0, 0, 0, 1);
158     Matrix4 V = Matrix4(
159                         1, 0, 0, 0,
160                         0, 1, 0, 0,
161                         0, 0, 1, 0,
162                         0, 0, 0, 1);
163     Matrix4 P = Matrix4(
164                         1, 0, 0, 0,
165                         0, 1, 0, 0,
166                         0, 0, -1, 0,
167                         0, 0, 0, 1);
168
169     Matrix4 MVP = P*V*M;
170
171     GLfloat mvp[16];
172     // row-major ---> column-major
173     mvp[0] = MVP[0];  mvp[4] = MVP[1];   mvp[8]  = MVP[2];    mvp[12] = MVP[3];
174     mvp[1] = MVP[4];  mvp[5] = MVP[5];   mvp[9]  = MVP[6];    mvp[13] = MVP[7];
175     mvp[2] = MVP[8];  mvp[6] = MVP[9];   mvp[10] = MVP[10];   mvp[14] = MVP[11];
176     mvp[3] = MVP[12]; mvp[7] = MVP[13];  mvp[11] = MVP[14];   mvp[15] = MVP[15];
177
```

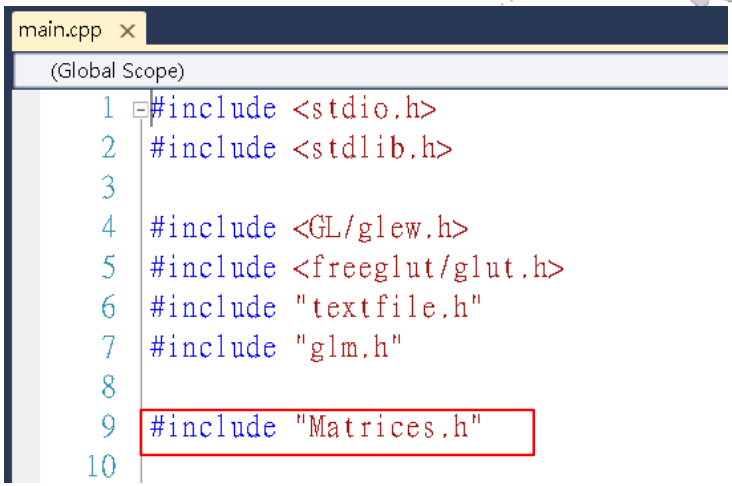
move -0.5 in x direction





Useful Library

- Files
  - Matrices.cpp
  - Matrices.h
  - Vectors.h



- Put these files under the same folder as main.cpp

Useful Library

Matrices.h

(Global Scope)

```
131
132 ///////////////////////////////////////////////////////////////////////
133 // 4x4 matrix
134 ///////////////////////////////////////////////////////////////////////
135 class Matrix4
136 {
137 public:
138     // constructors
139     Matrix4();  // init with identity
140     Matrix4(const float src[16]);
141     Matrix4(float xx, float xy, float xz, float xw,
142             float yx, float yy, float yz, float yw,
143             float zx, float zy, float zz, float zw,
144             float wx, float wy, float wz, float ww);
145
146     void        set(const float src[16]);
147     void        set(float xx, float xy, float xz, float xw,
148                     float yx, float yy, float yz, float yw,
149                     float zx, float zy, float zz, float zw,
```

Vectors.h

Vector3 | Vector3(float x, float y, float z)

```
67 struct Vector3
68 {
69     float x;
70     float y;
71     float z;
72
73     // ctors
74     Vector3() : x(0), y(0), z(0) {};
75     Vector3(float x, float y, float z) : x(x), y(y), z(z) {};
76
77     // utils functions
78     void        set(float x, float y, float z);
79     float       length() const;                         //
80     float       distance(const Vector3& vec) const;     // distance between two vectors
81     Vector3&    normalize();                            //
82     float       dot(const Vector3& vec) const;          // dot product
83     Vector3     cross(const Vector3& vec) const;        // cross product
84     bool        equal(const Vector3& vec, float e) const; // compare with epsilon
```

Control (Keyboard)

Mode	Manipulation	Key
Translation	Change (x ,y, z)	T
Scaling		S
Rotation		R
Eye position		E
Center position		L
Help menu	Show help menu	H
Switch Projection	Switch between parallel / perspective projection	O
Change model	Previous / next model as hw1	Z / X
Projection transformation	Change up, down, right, left, near, far of projection parameter	P

Control (Mouse)

Geometrical / Viewing transformation mode

Button	Manipulation
Left	Drag horizontal for **x** offset Drag vertically for **y** offset
Right	Same as left
Middle	Wheel up/down for **z** offset

Projection transformation mode

Button	Manipulation
Left	Drag horizontal for **left-right** boundary scaling Drag vertically for **bottom-top** boundary scaling
Right	Drag horizontal for **moving near clipping plane** Drag vertically for **moving far clipping plane**
Middle	none


Q
&
A