HW1 Tutorial

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Reference

1.BASIC GLUT

About **main()** function in basicDraw.cpp

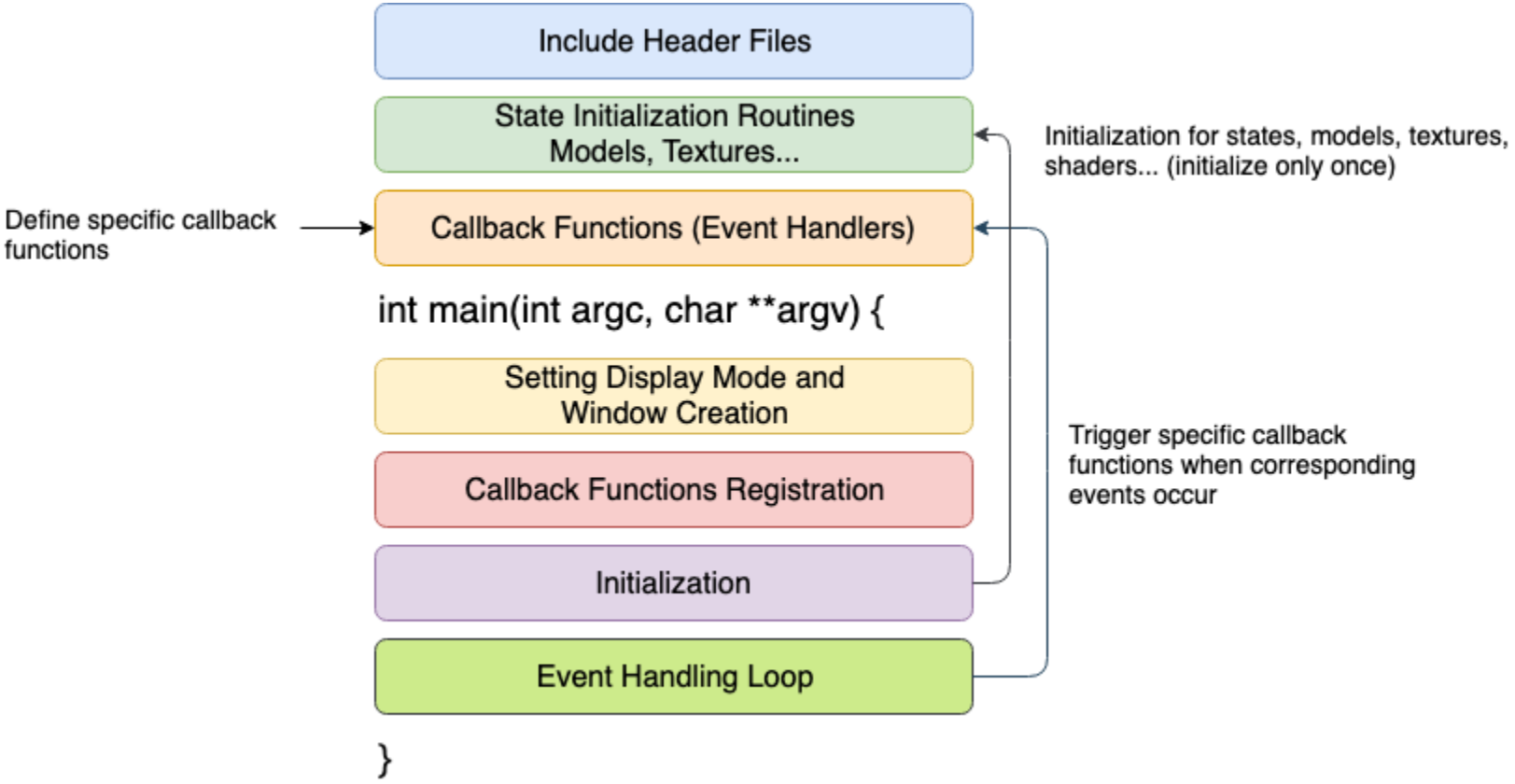
1-1 Document

- https://www.opengl.org/resources/libraries/glut/spec3/spec3.html

The OpenGL Utility Toolkit (GLUT) Programming Interface API Version 3

Mark J. Kilgard
Silicon Graphics, Inc.

1-2 OpenGL Architecture



1-3 Initialization and window

- void **glutInit**(int* argc, char **argv);
  - Initialize the GLUT library
  - Should be called before any GLUT functions
- void **glutInitDisplayMode**(unsigned int mode); (Red are commonly used parameters)
  - Specify a display mode for windows created
  - Color: GLUT_RGBA, GLUT_RGB or GLUT_INDEX
  - Framebuffer: GLUT_SINGLE or GLUT_DOUBLE
  - Buffer: GLUT_DEPTH, GLUT_STENCIL and GLUT_ACCUM

```
int main(int argc, char** argv)
{
    glutInit(&argc, argv);
    glutInitDisplayMode(GLUT_DOUBLE | GLUT_RGB | GLUT_DEPTH);
    glutInitWindowSize(width, height);
    glutInitWindowPosition(0, 0);
    glutCreateWindow("WindowName");

    glutDisplayFunc(display);
    glutReshapeFunc(reshape);
    glutKeyboardFunc(keyboard);
    glutMouseFunc(mouse);
    glutMotionFunc(mouseMotion);
    glutPassiveMotionFunc(passiveMouseMotion);
    glutIdleFunc(idle);

    glutMainLoop();

    return 0;
}
```

1-3 Initialization and window

- void **glutInitWindowSize**(int width, int height);
  - Set the initial window size
- void **glutInitWindowPosition**(int x, int y);
  - Set the initial window position
  - The actual position is left to the window system to determine
- int **glutCreateWindow**(char *name);
  - Create and open a window with previous settings

```
int main(int argc, char** argv)
{
    glutInit(&argc, argv);
    glutInitDisplayMode(GLUT_DOUBLE | GLUT_RGB | GLUT_DEPTH);
    glutInitWindowSize(width, height);
    glutInitWindowPosition(0, 0);
    glutCreateWindow("WindowName");

    glutDisplayFunc(display);
    glutReshapeFunc(reshape);
    glutKeyboardFunc(keyboard);
    glutMouseFunc(mouse);
    glutMotionFunc(mouseMotion);
    glutPassiveMotionFunc(passiveMouseMotion);
    glutIdleFunc(idle);

    glutMainLoop();

    return 0;
}
```

1-3 Initialization and window

- void **glutPostRedisplay**();
  - Mark the current window as needing to be redisplayed
  - The window‘s display callback will be called GLfloat
- void **glutSwapBuffers**();
  - Swap the buffers of the current window
  - An implicit glFlush() is done by glutSwapBuffers()

```
void idle() {
    glutPostRedisplay();
}
```

```
glBegin(GL_TRIANGLES);
//red triangle (z = 0)
glColor3f(1.0f, 0.0f, 0.0f);
glVertex3f(1.0f, 0.0f, 0.0f);
glColor3f(1.0f, 0.0f, 0.0f);
glVertex3f(0.0f, 1.0f, 0.0f);
glColor3f(1.0f, 0.0f, 0.0f);
glVertex3f(0.0f, 0.0f, 0.0f);
//blue triangle (z = -1)
glColor3f(0.0f, 0.0f, 1.0f);
glVertex3f(1.0f, 0.0f, -1.0f);
glColor3f(0.0f, 0.0f, 1.0f);
glVertex3f(0.0f, 1.0f, -1.0f);
glColor3f(0.0f, 0.0f, 1.0f);
glVertex3f(0.0f, 0.0f, -1.0f);

glEnd();
// In display function
glutSwapBuffers();
```

1-4 Callback Registration

- void **glutDisplayFunc**(void (*func)(void));
  - Put whatever you want to render in the callback
  - The callback is called when the window need to be redisplayed
  - Call glutPostRedisplay() to trigger the callback
- void **glutReshapeFunc**(void (*func)(int width, int height));
  - The callback is called when a window is created, resized or moved
  - Always call glViewport() to resize your viewport
- void **glutIdleFunc**(void (*func)(void));
  - Perform background processing tasks or continuous animation when window system events are not being received
  - The idle callback is continuously called when events are not being received

```
int main(int argc, char** argv)
{
    glutInit(&argc, argv);
    glutInitDisplayMode(GLUT_DOUBLE | GLUT_RGB | GLUT_DEPTH);
    glutInitWindowSize(width, height);
    glutInitWindowPosition(0, 0);
    glutCreateWindow("WindowName");

    glutDisplayFunc(display);
    glutReshapeFunc(reshape);
    glutKeyboardFunc(keyboard);
    glutMouseFunc(mouse);
    glutMotionFunc(mouseMotion);
    glutPassiveMotionFunc(passiveMouseMotion);
    glutIdleFunc(idle);

    glutMainLoop();

    return 0;
}
```

1-4 Callback Registration

- void **glutKeyboardFunc**(void (*func)(unsigned char key, int x, int y));
  - Each key press generates a keyboard callback
  - key: The ASCII character generated by the pressed key
  - x and y: The mouse location in window relative coordinates when the key was pressed

```
int main(int argc, char** argv)
{
    glutInit(&argc, argv);
    glutInitWindowSize(500, 500);
    glutInitWindowPosition(0, 0);
    glutInitDisplayMode(GLUT_DOUBLE | GLUT_RGB);
    glutCreateWindow("HW1");
    glutDisplayFunc(display);
    glutReshapeFunc(reshape);
    glutKeyboardFunc(keyboard);
    glutMainLoop();
    return 0;
}
```

1-5 Geometric Object Rendering

- void **glutSolidSphere**(Gldouble size, GLint slices, GLint stacks);
- void **glutWireSphere**(Gldouble size, GLint slices, GLint stacks);
- void **gluCylinder**(GLUquadric* quad, GLdouble base, GLdouble top,
  GLdouble height, GLint slices, GLint stacks);
- void **glutSolidCube**(Gldouble size); void **glutWireCube**(Gldouble size);
- void **glutSolidCone**(Gldouble size); void **glutWireCone**(Gldouble size);
- void **glutSolidTorus**(Gldouble size);void **glutWireTorus**(Gldouble size);
- void **glutSolidTeapot**(Gldouble size); void **glutWireTeapot**(Gldouble size);

1-6 Beginning Event Processing

- void glutMainLoop();
  - Enter the GLUT event processing loop
  - Once called, this routine will never return

```
int main(int argc, char** argv)
{
    glutInit(&argc, argv);
    glutInitDisplayMode(GLUT_DOUBLE | GLUT_RGB | GLUT_DEPTH);
    glutInitWindowSize(width, height);
    glutInitWindowPosition(0, 0);
    glutCreateWindow("WindowName");

    glutDisplayFunc(display);
    glutReshapeFunc(reshape);
    glutKeyboardFunc(keyboard);
    glutMouseFunc(mouse);
    glutMotionFunc(mouseMotion);
    glutPassiveMotionFunc(passiveMouseMotion);
    glutIdleFunc(idle);

    glutMainLoop();

    return 0;
}
```

2.BASIC DRAW

About display() function in basicDraw.cpp

2-1. In the function **display()** of basicDraw.cpp,
We do the following things,

1. Set up the MVP matrix (Mentioned later in the Section. 3 OpenGL-Transform)

2. Before drawing, we need to clear the color buffer and depth buffer by **glClear()** with the values set by **glClearColor()** and **glClearDepth()**

3. Enable the option for depth test so the face behind other faces would not render in the front

4. Draw two triangles by glColor3f() and glVertex3f() between **glBegin(), glEnd()**

5. In the end, swap the buffers by **glutSwapBuffers()**

In the next pages, we will introduce the openGL functions used in these steps since step2. And if you want to know more detailed information about the functions, please go to the link:
https://www.khronos.org/registry/OpenGL-Refpages/gl2.1/

```
//ModelView Matrix
glMatrixMode(GL_MODELVIEW);
glLoadIdentity();
gluLookAt(0.0f, 0.0f, 10.0f, 0.0f, 0.0f, 0.0f, 0.0f, 1.0f, 0.0f);
//Projection Matrix
glMatrixMode(GL_PROJECTION);
glLoadIdentity();
gluPerspective(45, width / (GLfloat)height, 0.1, 1000);
//Viewport Matrix
glViewport(0, 0, width, height);

//
glMatrixMode(GL_MODELVIEW);
glClearColor(0.0f, 0.0f, 0.0f, 0.0f);
glClear(GL_COLOR_BUFFER_BIT);
glClearDepth(1.0);
glEnable(GL_DEPTH_TEST);    //depth test
glDepthFunc(GL_LEQUAL);
glClear(GL_DEPTH_BUFFER_BIT);

glBegin(GL_TRIANGLES);
//red triangle (z = 0)
glColor3f(1.0f, 0.0f, 0.0f);
glVertex3f(1.0f, 0.0f, 0.0f);
glColor3f(1.0f, 0.0f, 0.0f);
glVertex3f(0.0f, 1.0f, 0.0f);
glColor3f(1.0f, 0.0f, 0.0f);
glVertex3f(0.0f, 0.0f, 0.0f);
//blue triangle (z = -1)
glColor3f(0.0f, 0.0f, 1.0f);
glVertex3f(1.0f, 0.0f, -1.0f);
glColor3f(0.0f, 0.0f, 1.0f);
glVertex3f(0.0f, 1.0f, -1.0f);
glColor3f(0.0f, 0.0f, 1.0f);
glVertex3f(0.0f, 0.0f, -1.0f);

glEnd();

glutSwapBuffers();
```

STEP1
STEP2
STEP3
STEP4
STEP5

2-2. Clear color buffer & Clear depth buffer

Before we start a new render iteration, we need to clear our color buffer and depth buffer, otherwise you're stuck with the written color values and depth values from the last render iteration.
Here are the functions used for buffer cleaning:

- void **glClearColor**(GLfloat red,
  GLfloat green,
  GLfloat blue,
  GLfloat alpha);

Specify the red, green, blue, and alpha values used when the color buffers are cleared. The initial values are all 0. (black)

- void **glClearDepth**(GLdouble depth);

Specify the depth value used when the depth buffer is cleared. The initial value is 1. The depth is in the range [0, 1].

```
//
glMatrixMode(GL_MODELVIEW);
glClearColor(0.0f, 0.0f, 0.0f, 0.0f);
glClear(GL_COLOR_BUFFER_BIT);
glClearDepth(1.0);
glEnable(GL_DEPTH_TEST);    //depth test
glDepthFunc(GL_LEQUAL);
glClear(GL_DEPTH_BUFFER_BIT);
```

- void **glClear**(GLbitfield mask);

Clear the specified buffers to their current clearing values selected by glClearColor(), glClearDepth(), and glClearStencil().

mask: **GL_COLOR_BUFFER_BIT, GL_DEPTH_BUFFER_BIT,**
GL_STENCIL_BUFFER_BIT

EX:
glClear(GL_COLOR_BUFFER_BIT |GL_DEPTH_BUFFER_BIT);

2-3. Enable depth test

In order to prevent faces rendering to the front while they're behind other faces, we need to enable depth test before drawing:
Here are the functions for enabling depth test:

- **glEnable**(GL_DEPTH_TEST);

When depth test is enabled, OpenGL tests the depth value of a fragment against the content of the depth buffer. If this test passes, the depth buffer is updated with the new depth value. If the test fails, the fragment is discarded.

- void **glDepthFunc**(GLenum func);

Specify the depth comparison function for the depth test.
func: GL_NEVER, GL_LESS, GL_EQUAL, GL_LEQUAL, GL_GREATER... The initial value is GL_LESS
Ex. glDepthFunc(GL_LEQUAL); =>
if (fragment's depth value <= stored depth value) pass.

```
//
glMatrixMode(GL_MODELVIEW);
glClearColor(0.0f, 0.0f, 0.0f, 0.0f);
glClear(GL_COLOR_BUFFER_BIT);
glClearDepth(1.0);
glEnable(GL_DEPTH_TEST);    //depth test
glDepthFunc(GL_LEQUAL);
glClear(GL_DEPTH_BUFFER_BIT);
```

If you are interested in more information about depth test:

https://learnopengl.com/Advanced-OpenGL/Depth-testing

2-4. Draw the triangles

By the help of OpenGL, we can draw our triangles by simply setting the vertex data **between glBegin() and glEnd()**

- void **glBegin**(Glenum mode);

Marks the beginning of a vertex-data list.
Vertex-data include vertex's color, normal, position, etc.
The mode specifies the primitive or primitives that will be created from vertices presented between glBegin() and glEnd().

- void **glEnd**();

Marks the end of a vertex-data list

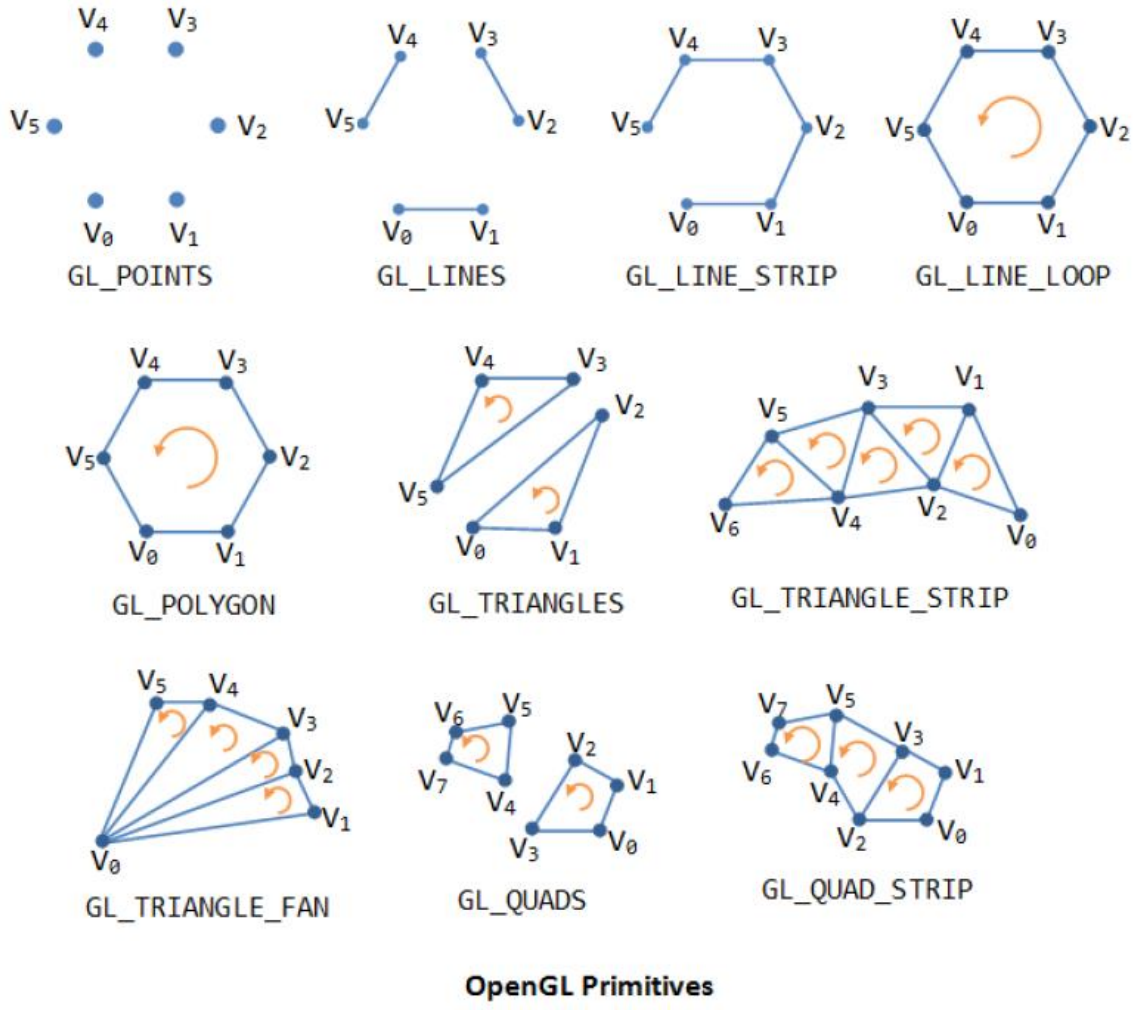
```
glBegin(GL_TRIANGLES);
//red triangle (z = 0)
glColor3f(1.0f, 0.0f, 0.0f);
glVertex3f(1.0f, 0.0f, 0.0f);
glColor3f(1.0f, 0.0f, 0.0f);
glVertex3f(0.0f, 1.0f, 0.0f);
glColor3f(1.0f, 0.0f, 0.0f);
glVertex3f(0.0f, 0.0f, 0.0f);
//blue triangle (z = -1)
glColor3f(0.0f, 0.0f, 1.0f);
glVertex3f(1.0f, 0.0f, -1.0f);
glColor3f(0.0f, 0.0f, 1.0f);
glVertex3f(0.0f, 1.0f, -1.0f);
glColor3f(0.0f, 0.0f, 1.0f);
glVertex3f(0.0f, 0.0f, -1.0f);

glEnd();

glutSwapBuffers();
```

2-4. Draw the triangles

mode of glBegin() :



OpenGL Primitives

2-4. Draw the triangles

Can only be effective between glBegin() and glEnd() pair

- void **glColor**{34}{sifd}[v](…);
  Set the current color

- void **glMaterialfv**(GLenum face,
  GLenum pname,
  const GLfloat *params);
  Specify material parameters for the lighting model
  (If HW1 use lighting, use this to set the color!)

- void **glNormal3**{bsifd}[v](…)
  Set the current normal vector

- void **glVertex**{234}{sifd}[v](…)
  Specify a vertex for use in describing a geometric object

You have to set vertex's attributes before glVertex

Ex: Use **glColor()** and **glNormal()** before **glVertex()** to set the vertex's color and normal.

```
glBegin(GL_TRIANGLES);
//red triangle (z = 0)
glColor3f(1.0f, 0.0f, 0.0f);
glVertex3f(1.0f, 0.0f, 0.0f);
glColor3f(1.0f, 0.0f, 0.0f);
glVertex3f(0.0f, 1.0f, 0.0f);
glColor3f(1.0f, 0.0f, 0.0f);
glVertex3f(0.0f, 0.0f, 0.0f);
//blue triangle (z = -1)
glColor3f(0.0f, 0.0f, 1.0f);
glVertex3f(1.0f, 0.0f, -1.0f);
glColor3f(0.0f, 0.0f, 1.0f);
glVertex3f(0.0f, 1.0f, -1.0f);
glColor3f(0.0f, 0.0f, 1.0f);
glVertex3f(0.0f, 0.0f, -1.0f);

glEnd();

glutSwapBuffers();
```

2-5. Complete drawing

Don’t forget to swap the buffers when you complete drawing

- void **glutSwapBuffers();**
  Swap the front and back buffers.

```
glBegin(GL_TRIANGLES);
//red triangle (z = 0)
glColor3f(1.0f, 0.0f, 0.0f);
glVertex3f(1.0f, 0.0f, 0.0f);
glColor3f(1.0f, 0.0f, 0.0f);
glVertex3f(0.0f, 1.0f, 0.0f);
glColor3f(1.0f, 0.0f, 0.0f);
glVertex3f(0.0f, 0.0f, 0.0f);
//blue triangle (z = -1)
glColor3f(0.0f, 0.0f, 1.0f);
glVertex3f(1.0f, 0.0f, -1.0f);
glColor3f(0.0f, 0.0f, 1.0f);
glVertex3f(0.0f, 1.0f, -1.0f);
glColor3f(0.0f, 0.0f, 1.0f);
glVertex3f(0.0f, 0.0f, -1.0f);

glEnd();

glutSwapBuffers();
```

2-6 Face culling

OpenGL checks and renders all the faces that are front facing towards the viewer while discarding all the back face.

- **glEnable**(GL_CULL_FACE);

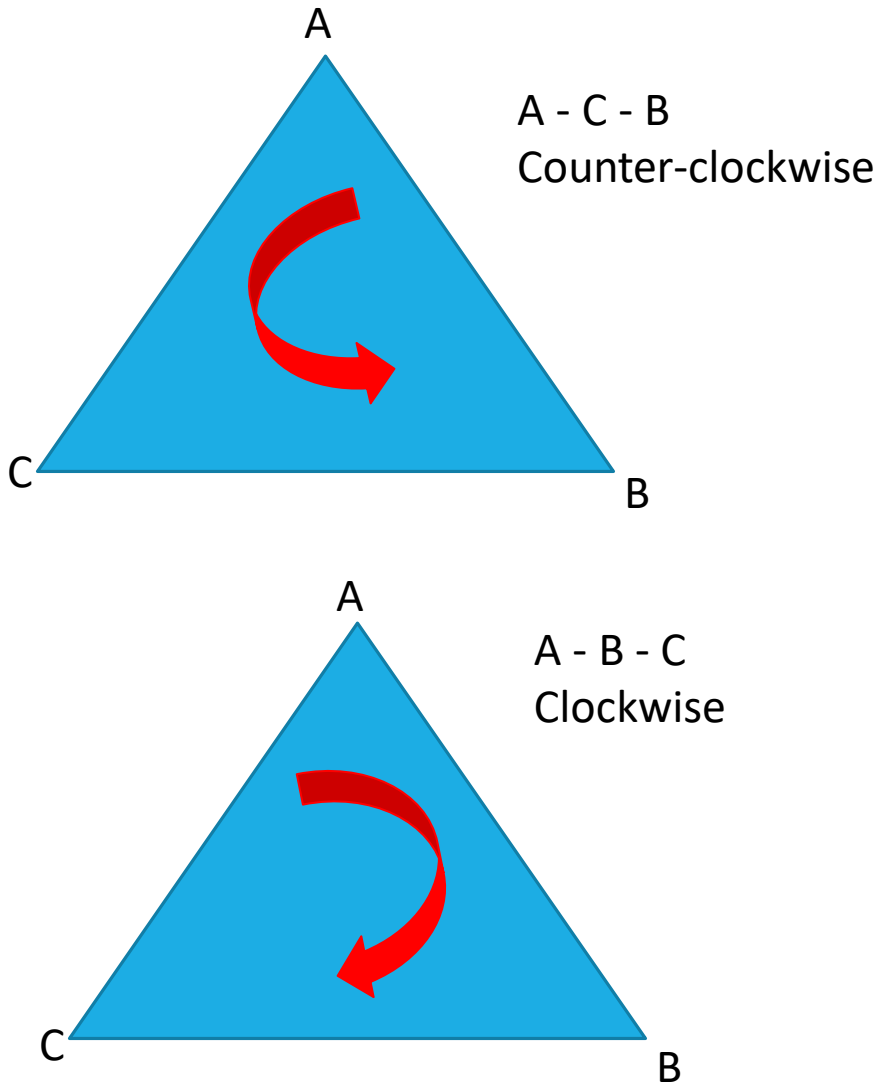
  Enable OpenGL's GL_CULL_FACE option.

- void **glCullFace** (GLenum mode)

  Specify whether front or back facing faces can be culled.
  mode: GL_BACK,GL_FRONT,GL_FRONT_AND_BACK
  Ex. glCullFace(GL_BACK) culls only the back faces. OpenGL allows us to change the type of face that we want to cull as well.

- void **glFrontFace** (GLenum mode);

  Define front and back facing polygons
  mode: GL_CW, GL_CCW. The default value is GL_CCW.
  Ex. glFrontFace(GL_CCW) =>counter-clockwise ordering

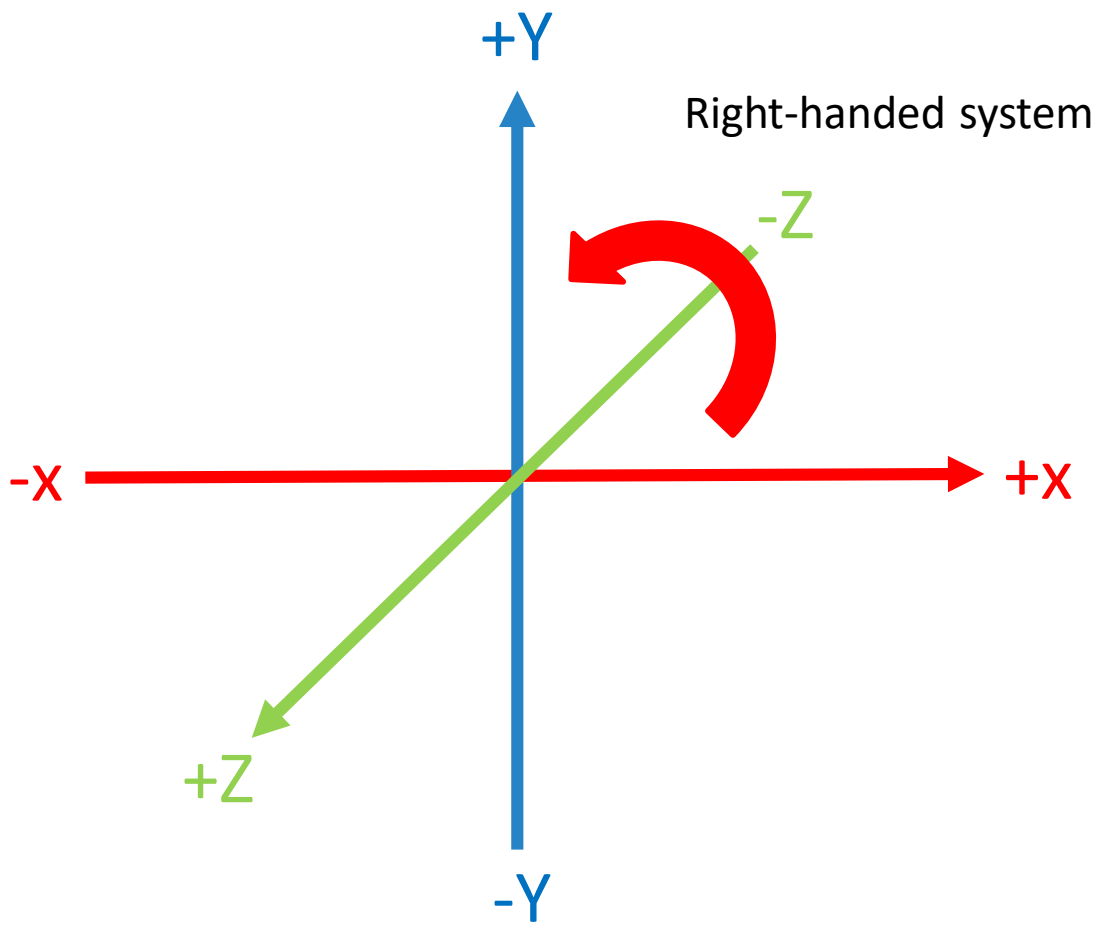


2-7 More Information about OpenGL …
OpenGL data type

Table 3-2 OpenGL variable types and corresponding C data types

OpenGL Data Type	Internal Representation	Defined as C Type	C Literal Suffix
GLbyte	8-bit integer	Signed char	b
GLshort	16-bit integer	Short	s
GLint, GLsizei	32-bit integer	Long	I
GLfloat, GLclampf	32-bit floating point	Float	f
GLdouble, GLclampd	64-bit floating point	Double	d
GLubyte, GLboolean	8-bit unsigned integer	Unsigned char	ub
GLushort	16-bit unsigned integer	Unsigned short	us
GLuint, GLenum, GLbitfield	32-bit unsigned integer	Unsigned long	ui

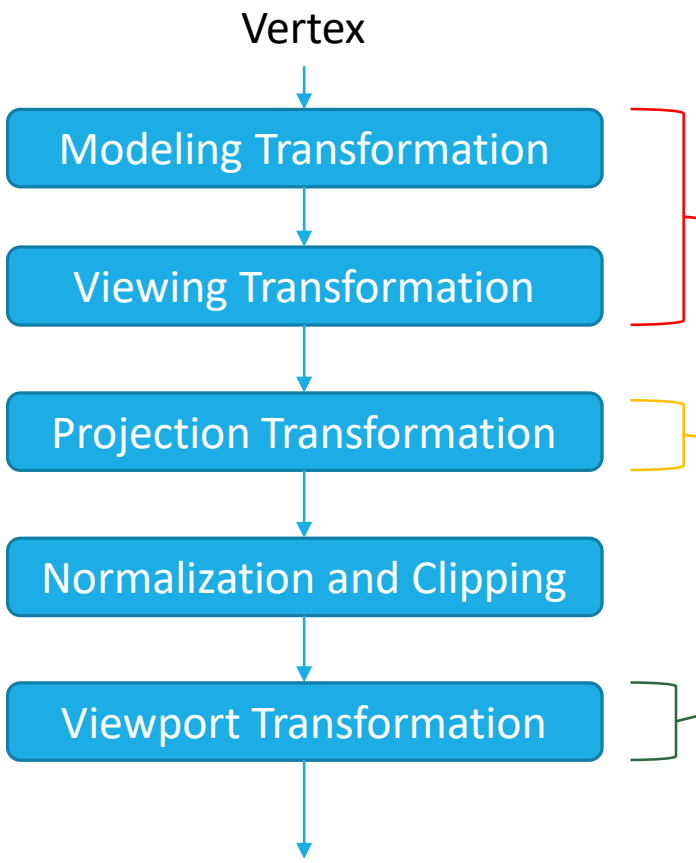
2-7 More Information about OpenGL …
OpenGL coordinate system



OpenGL-Transform

How to rotate the planet in OpenGL?

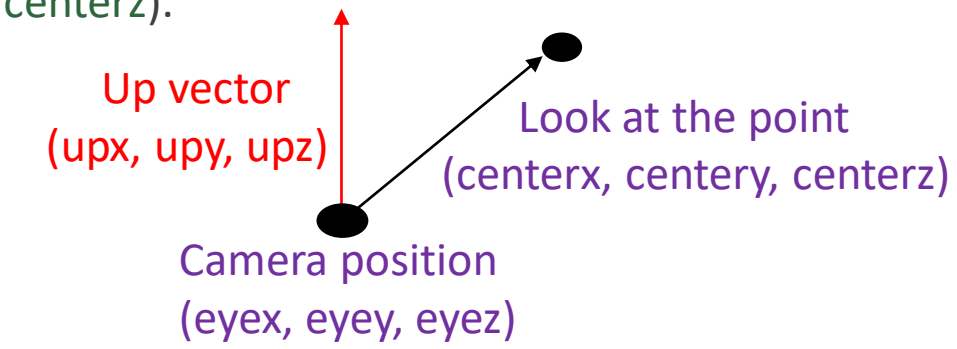
3-1 Overview




```
void display()
{
    //ModelView Matrix
    glMatrixMode(GL_MODELVIEW);
    glLoadIdentity();
    gluLookAt(0.0f, 0.0f, 10.0f, 0.0f, 0.0f, 0.0f, 0.0f, 1.0f, 0.0f);
    //Projection Matrix
    glMatrixMode(GL_PROJECTION);
    glLoadIdentity();
    gluPerspective(45, width / (GLfloat)height, 0.1, 1000);
    //Viewport Matrix
    glViewport(0, 0, width, height);
```

3-2 ModelView Matrix

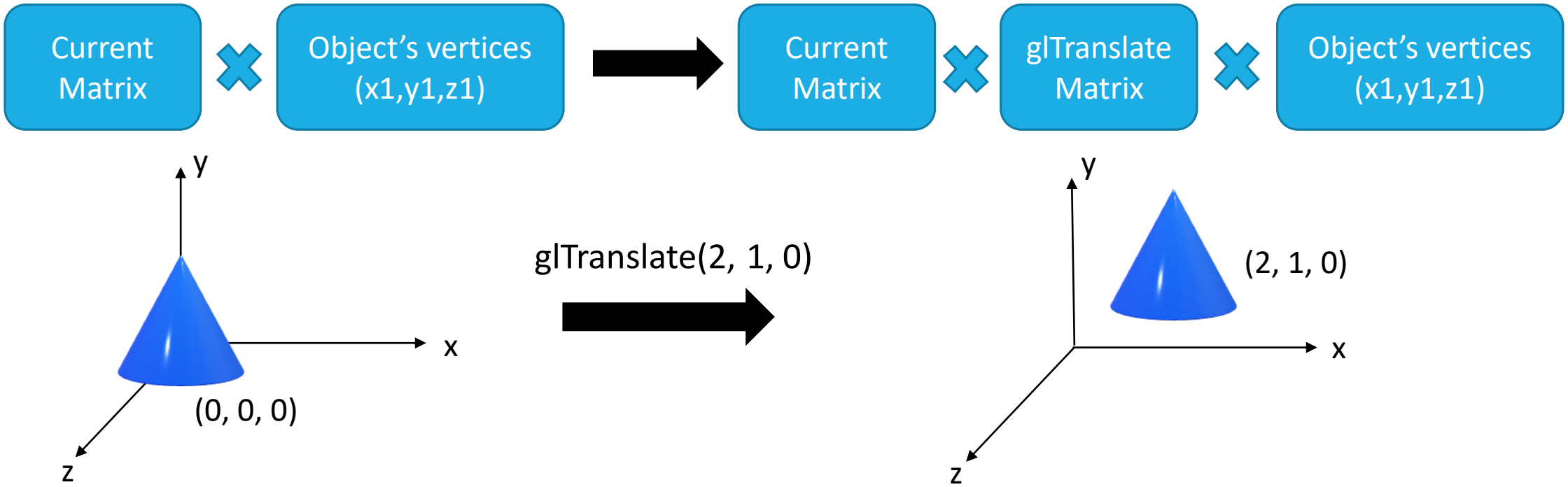
- void **glMatrixMode** (GLenum mode);
  - There are three different modes : GL_MODELVIEW, GL_PROJECTION, or GL_TEXTURE.
  - Each mode has its corresponding matrix stack, and only one matrix stack is active at a time.
- void **glLoadIdentity** (void);
  - Replace the current matrix with the identity matrix.
- void **gluLookAt** (GLdouble eyex, GLdouble eyey, GLdouble eyez, GLdouble centerx, GLdouble centery, GLdouble centerz, GLdouble upx, GLdouble upy, GLdouble upz);
  - Viewing direction is from (eyex, eyey, eyez) to (centerx, centery, centerz).
  - Camera's up vector is (upx, upy, upz).
  - Changing the parameters in gluLookAt() means changing the camera's position, not the object's position.



3-3 Modeling Transformation

➢void **glTranslate{fd}** (TYPE x, TYPE y, TYPE z);

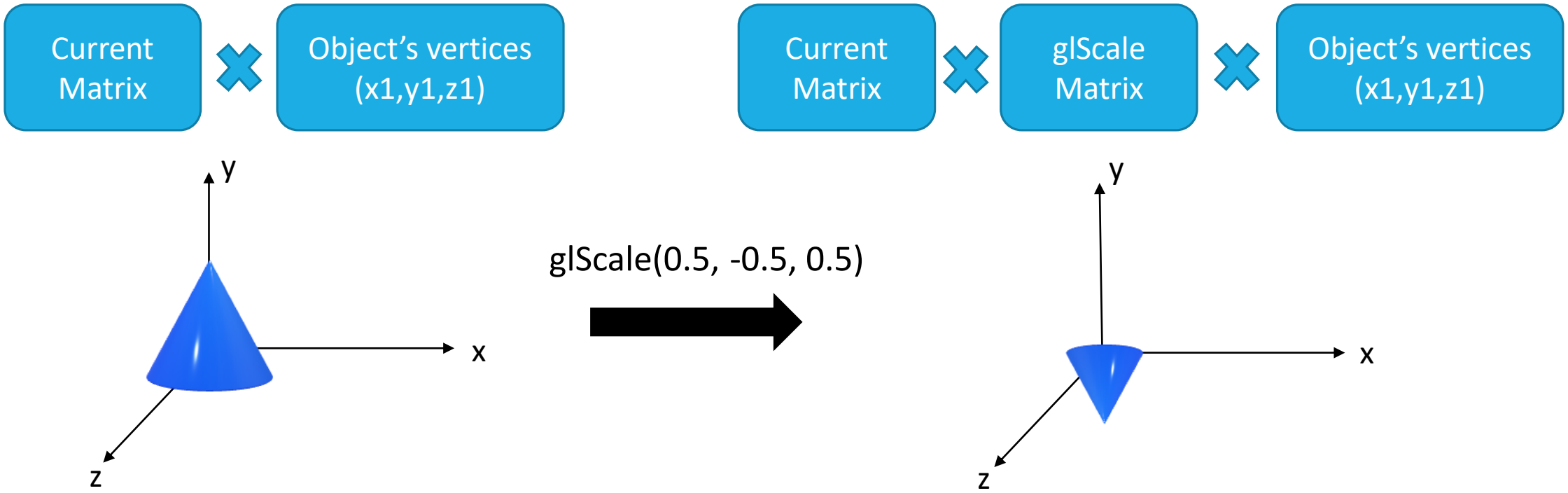
It will translate the object's vertices by the given x, y, z values.



3-3 Modeling Transformation

➢void **glScale{fd}**(TYPE x, TYPE y, TYPE z);

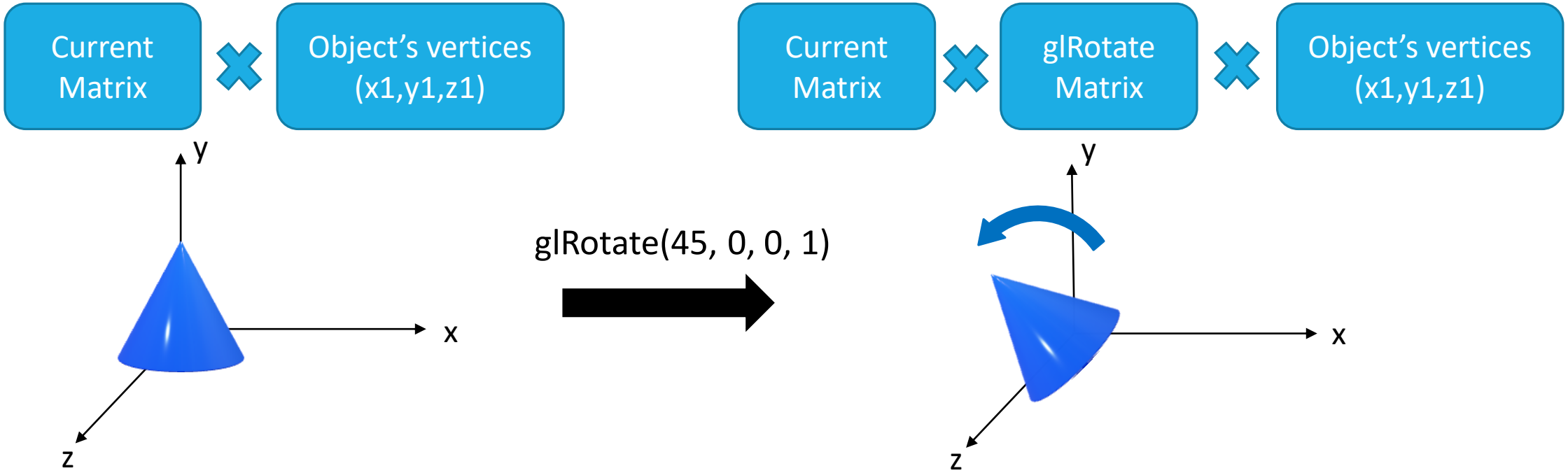
It will scale the object along the x, y, or z axes.



3-3 Modeling Transformation

➢void **glRotate{fd}**(TYPE angle, TYPE x, TYPE y, TYPE z);

It will rotate the object in a counterclockwise direction. The angle parameter is the angle of rotation in degrees. The rotating axis is from the origin to the point (x, y, z).



3-3 Modeling Transformation

In OpenGL, matrices multiplications are in reverse order when applied to the vertices.

.....

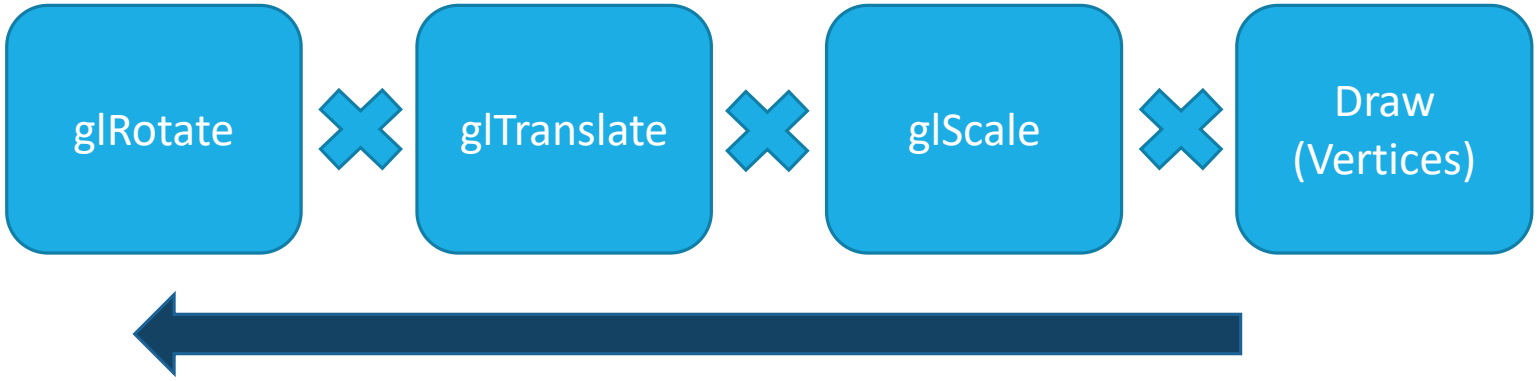
glRotate();

glTranslate();

glScale();

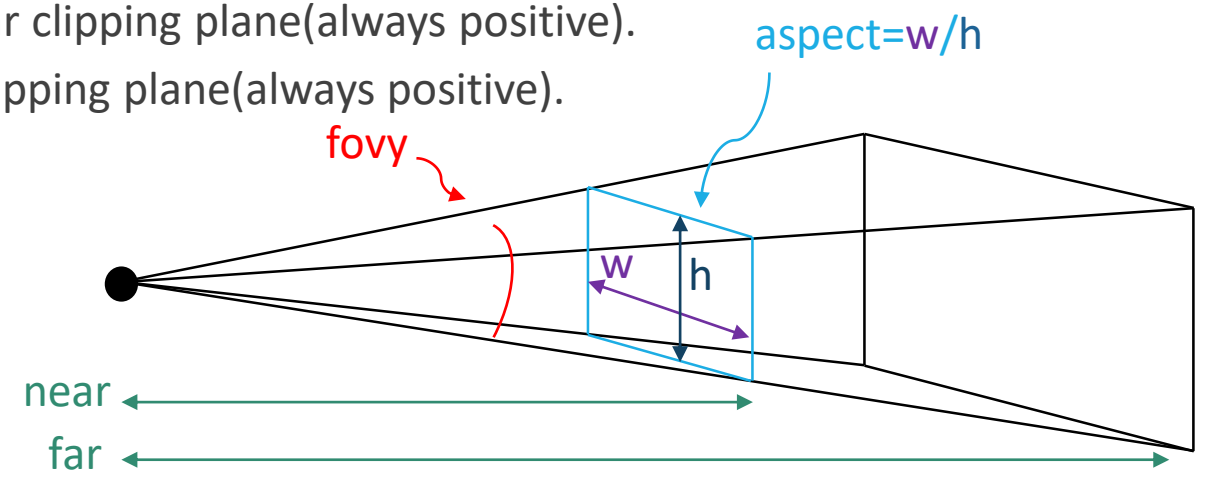
Draw();

.....



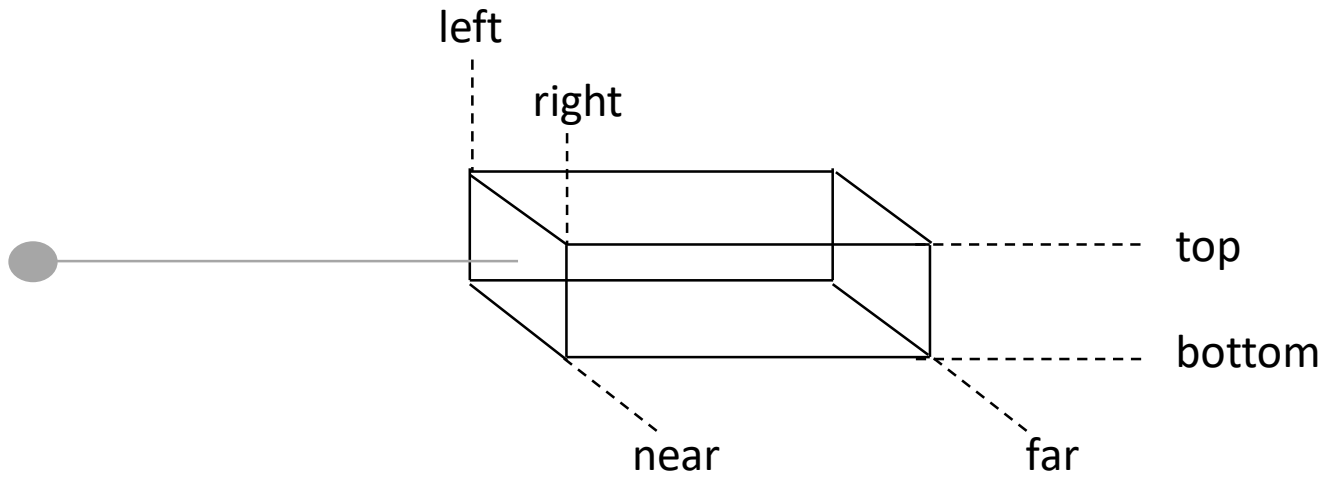
3-4 Projection Matrix --- Perspective Projection

- **glMatrixMode**(GL_PROJECTION);
- **glLoadIdentity**();
- void **gluPerspective** (GLdouble fovy, GLdouble aspect, GLdouble near, GLdouble far);
  - fovy : the angle of the field of view in the y direction.(in degrees)
  - aspect : the aspect ratio(w/h) that determines the field of view.
  - near : the distance between the viewer to the near clipping plane(always positive).
  - far : the distance between the viewer to the far clipping plane(always positive).



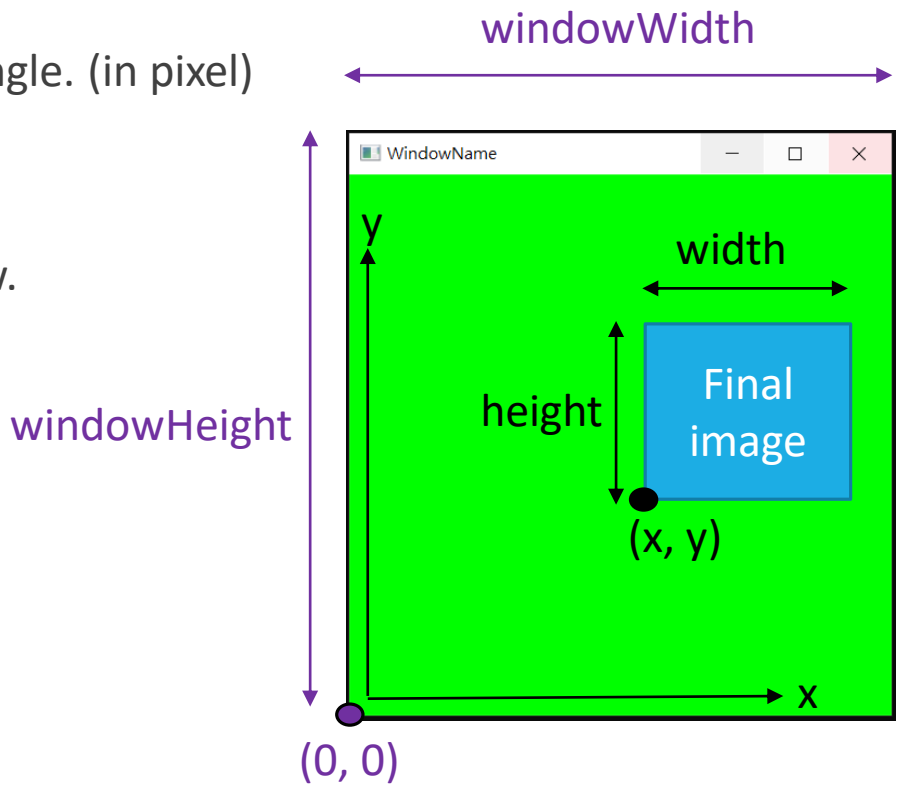
3-4 Projection Matrix --- Orthographic Projection

- void **glOrtho** (GLdouble left, GLdouble right, GLdouble bottom, GLdouble top, GLdouble near, GLdouble far);
  - left, right : the coordinates of the left and right vertical clipping planes.
  - bottom, top : the coordinates of the bottom and top horizontal clipping planes.
  - near, far : the coordinates of the near and far depth clipping planes.



3-5 Viewport Matrix

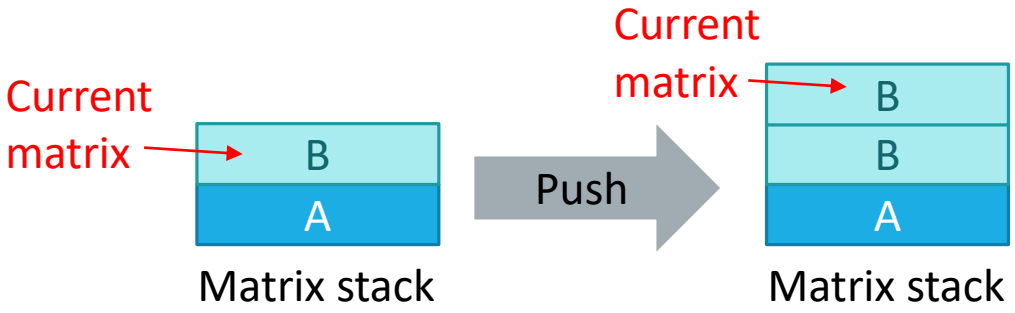
- void **glViewport** (GLint x, GLint y, GLsizei width, GLsizei height);
  - Map the final image to some region of the window.
  - The point (x, y) : the lower-left corner of the viewport rectangle. (in pixel)
  - width, height : the size of the viewport rectangle.
  - default value : (0, 0, windowWidth, windowHeight)
  - windowWidth and windowHeight are the size of the window.



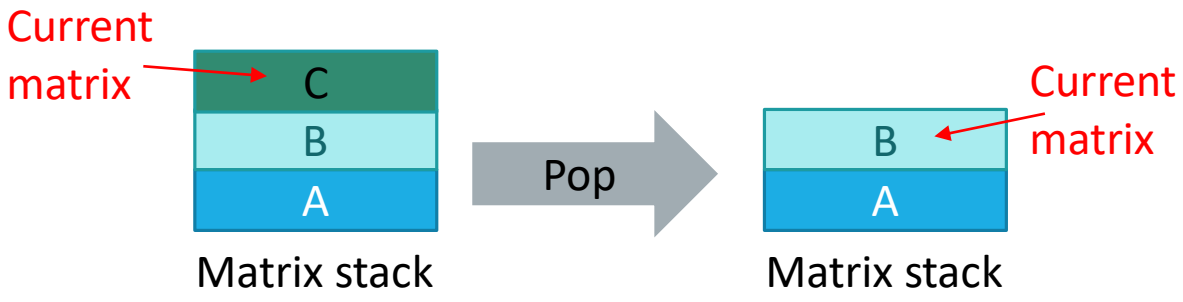
3-6 Matrix Stack Mechanism

- You can store certain transformation matrix on the matrix stack and easily get it when you want to reuse.
- The top of the matrix stack is the current matrix.
- Use **glPushMatrix()** and **glPopMatrix()** to manage the stack.

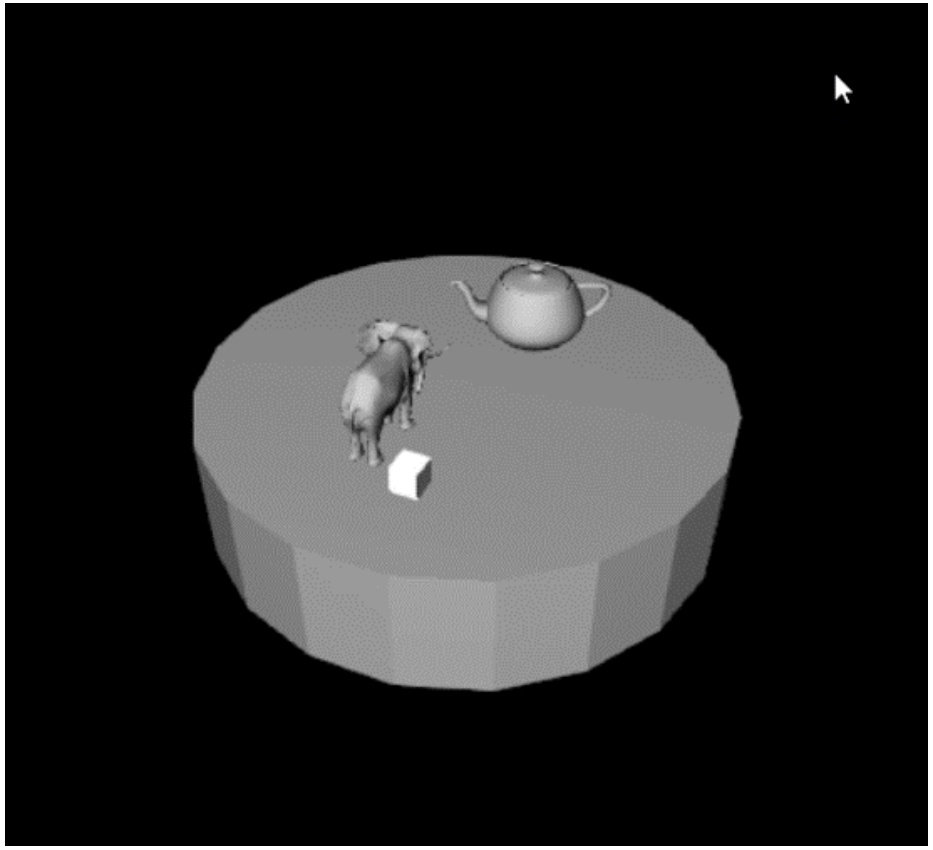
void **glPushMatrix()** :
Push the current matrix on the top of the stack.



void **glPopMatrix()** :
Pop the top matrix off the matrix stack.



3-7 Homework 1 - Music Box



3-7 Homework 1

Camera:

position: (20, 20, 20)

center: (0, 0, 0)

up vector: (0, 1, 0)

Fovy: 60

Near: 1.0

Far: 1000.0

整體轉速:

旋轉軸: y軸

1 degree/frame

(逆時鐘)

Cube & Elephant 轉速:

旋轉軸: y軸

3 degree/frame

(逆時鐘)

Cube 縮放:

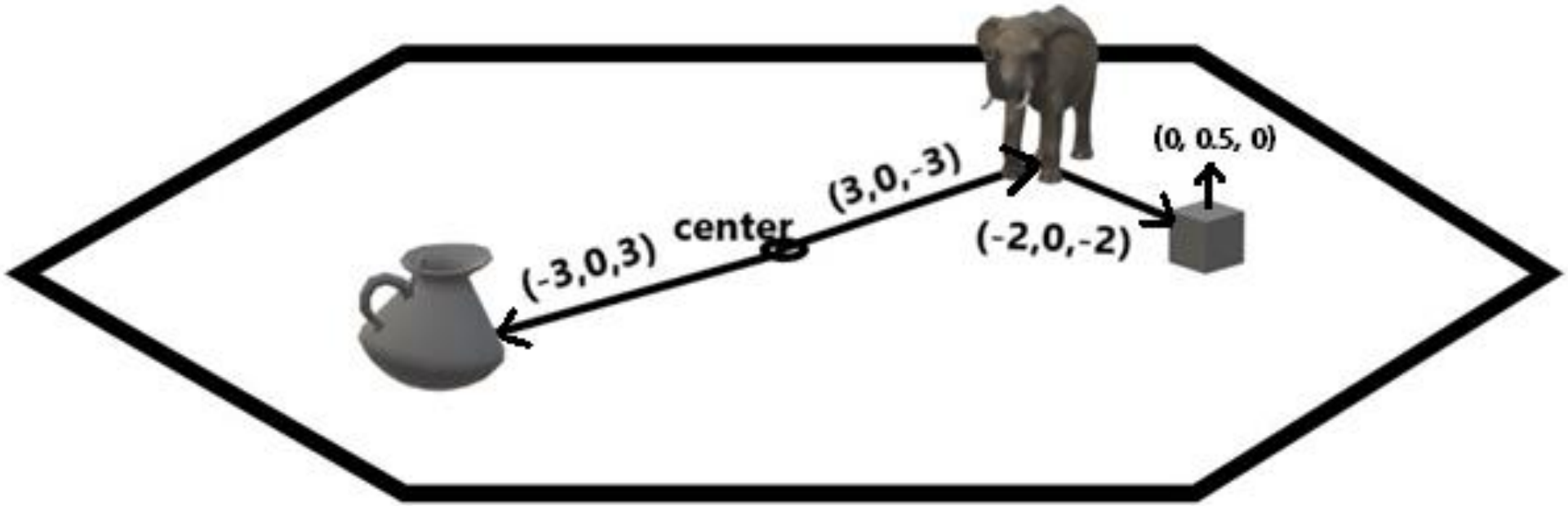
0.5 倍(長/寬/高)

3-7 Homework 1 (Basis)

edge = 20

radius = 10

3-7 Homework 1 (相對位置)



3-7 Homework 1 (配分)

1. Enable DepthTest (5%)
2. Add lighting, Viewport Matrix, Projection Matrix and ModelView Matrix (10%)
   (light is correct (5%) / glMatrixMode is correct (5%))
3. Draw Basis (25%)
4. Load model (5%)
5. translate (5%) /rotate (5%) / scale (5%) all correct (20%)
6. Demo – 問問題&改code (20%)

7. #加分 Set the keyboard control (5%) rotate camera/ object or some what..

3-7 Homework 1 (繳交規則)

1. DeadLine: 2020/ 10 / 26 23: 59:59

2. Penalty of 10% of the value of the assignment per late week.

If you submit your homework late, the score will be discounted.

submit between (10/27 - 11/2) : Your final score * 0.9

submit between (11/3 - 11/9) : Your final score * 0.8

submit after 11/9 : Your final score * 0.7

Reference

https://www.khronos.org/registry/OpenGL-Refpages/gl2.1/

https://learnopengl.com/

http://opengl.czweb.org/ch03/031-034.html