KAIST

CS 380

Introduction to Computer Graphics

LAB (1) : OpenGL Tutorial

2015.03.04

Reference : Foundations of 3D Computer Graphics, Steven J. Gortler

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Goals

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- Understand OpenGL pipeline
- Practice basic OpenGL programming
- Set up a project for OpenGL programs

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OpenGL with GLSL

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- OpenGL
  - Open Graphics Library
  - Cross-language and multi-platform API for rendering vector graphics
- GLSL
  - OpenGL Shading Language
  - Allow application programmers to express the processing that occurs at those programmable points of the OpenGL pipeline

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GLUT, GLEW

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- GLUT : The OpenGL Utility Toolkit
  - To open windows and to allow our program to respond to mouse and keyboard events
- GLEW : The OpenGL Extension Wrangler Library
  - To gain access to the latest features of OpenGL in Windows

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OpenGL Installation

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- Recommended Setup
  - Environment
    - Windows 32 bits or 64 bits
    - Visual Studio (c++)
  - OpenGL, GLUT and GLEW

    (we provide them as *asst0.zip* file)

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OpenGL Installation

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- Download 'asst0.zip' and extract it
- After compilation of the project, the debug or release folder would be created on the project folder
- Two files (glut32.dll, glew32.dll) in dll directory should be copied into directory which the exe file is in (debug or release folder)

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OpenGL Pipeline

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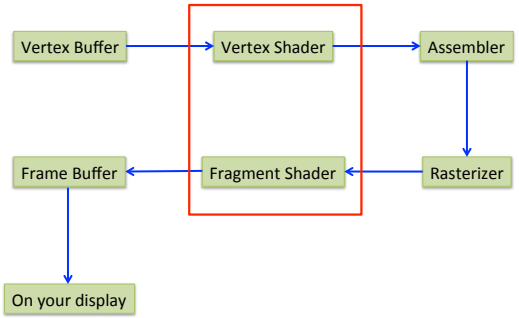

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Basic OpenGL

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- APIs

```
#include <GL/glew.h>
#ifdef __MAC__
#   include <GLUT/glut.h>
#else
#   include <GL/glut.h>
#endif
```


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Basic OpenGL

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- Main Program

```
int main(int argc, char **argv) {
  try {
    initGlutState(argc,argv);
    glewInit(); // load the OpenGL extensions

    cout << (g_Gl2Compatible ? "Will use OpenGL 2.x / GLS
    if ((!g_Gl2Compatible) && !GLEW_VERSION_3_0)
      throw runtime_error("Error: card/driver does not su
    else if (g_Gl2Compatible && !GLEW_VERSION_2_0)
      throw runtime_error("Error: card/driver does not su

    initGLState();
    initShaders();
    initGeometry();
    glutMainLoop();
    return 0;
  }
  catch (const runtime_error& e) {
    cout << "Exception caught: " << e.what() << endl;
    return -1;
  }
}
```


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Basic OpenGL

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- Main Program

```
int main(int argc, char **argv) {
  try {
    initGlutState(argc,argv);
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    initShaders();
    initGeometry();
    glutMainLoop();
    return 0;
  }
  catch (const runtime_error& e) {
    cout << "Exception caught: " << e.what() << endl;
    return -1;
  }
}
```


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Basic OpenGL

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- initGlutState()

```
static void initGlutState(int argc, char **argv){
  glutInit(&argc,argv);
  glutInitDisplayMode(GLUT_RGBA|GLUT_DOUBLE|GLUT_DEPTH);
  glutInitWindowSize(g_width, g_height);          // create a window
  glutCreateWindow("CS 380 : Hello World!!");     // title the window

  // callback functions
  glutDisplayFunc(display);                       // display rendering callback
  glutReshapeFunc(reshape);                       // window reshape callback
  glutMouseFunc(mouse);                           // mouse click callback
  glutKeyboardFunc(keyboard);                     // keyboard callback
}
```


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Callback Functions

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- Whenever some events occur, callback functions catch them and do some actions already defined

```
static void initGlutState(int argc, char **argv){
  glutInit(&argc,argv);
  glutInitDisplayMode(GLUT_RGBA|GLUT_DOUBLE|GLUT_DEPTH);
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  glutKeyboardFunc(keyboard);                     // keyboard callback
}
```


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Callback Functions

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- reshape();

```
static void reshape(int w, int h){
    g_width = w;
    g_height = h;
    glViewport(0, 0, w, h);
    glutPostRedisplay();
}
```


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Vertex Buffer

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```
static GLfloat sqPos[6 * 2] = {
    -0.5,  0.5,
    0.2,  0.2,
    0.3,  0.3
};

static GLfloat sqCol[6 * 3] =  {
    1, 1, 1,
    1, 0, 0,
    1, 1, 0,
};

glBindBuffer(GL_ARRAY_BUFFER, posVbo);
glBufferData(
  GL_ARRAY_BUFFER,
  12*sizeof(GLfloat),
  sqPos,
  GL_STATIC_DRAW);
checkGlErrors();


glBindBuffer(GL_ARRAY_BUFFER, colVbo);
glBufferData(
  GL_ARRAY_BUFFER,
  18*sizeof(GLfloat),
  sqCol,
  GL_STATIC_DRAW);
checkGlErrors();
```

Determine the initial coordinates and colors of vertices

Pass the program data to the OpenGL buffer

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Callback Functions

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- Whenever some events occur, callback functions catch them and do some actions already defined

```
static void initGlutState(int argc, char **argv){
  glutInit(&argc,argv);
  glutInitDisplayMode(GLUT_RGBA|GLUT_DOUBLE|GLUT_DEPTH);
  glutInitWindowSize(g_width, g_height);          // create a window
  glutCreateWindow("CS 380 : Hello World!!");     // title the window

  // callback functions
  glutDisplayFunc(display);                       // display rendering callback
  glutReshapeFunc(reshape);                       // window reshape callback
  glutMouseFunc(mouse);                           // mouse click callback
  glutKeyboardFunc(keyboard);                     // keyboard callback
}
```


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Display

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```
static void display(void){
  glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);

  const ShaderState& curSS = *g_shaderStates[0];
  glUseProgram(curSS.program);

  safe_glUniform1f(curSS.h_uVertexTemp, g_vertexTemp);
  safe_glUniform1f(curSS.h_uColorTemp, g_colorTemp);
  g_square->draw(curSS);

  glutSwapBuffers();

  // check for errors
  checkGlErrors();
}
```

```
void draw(const ShaderState& curSS) {
  int numverts=6;
  safe_glEnableVertexAttribArray(curSS.h_aPosition);
  safe_glEnableVertexAttribArray(curSS.h_aColor);

  glBindBuffer(GL_ARRAY_BUFFER, posVbo);
  safe_glVertexAttribPointer(curSS.h_aPosition,
                             2, GL_FLOAT, GL_FALSE, 0, 0);

  glBindBuffer(GL_ARRAY_BUFFER, colVbo);
  safe_glVertexAttribPointer(curSS.h_aColor,
                             3, GL_FLOAT, GL_FALSE, 0, 0);

  glDrawArrays(GL_TRIANGLES,0,numverts);

  safe_glDisableVertexAttribArray(curSS.h_aPosition);
  safe_glDisableVertexAttribArray(curSS.h_aColor);
}
```


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Vertex Shader

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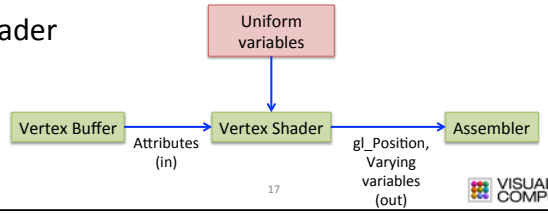
- Usually final positions of vertices on the screen are determined in the vertex shader
- When *draw* function is called, each vertex data in the vertex buffer passes through the vertex shader



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Vertex Shader

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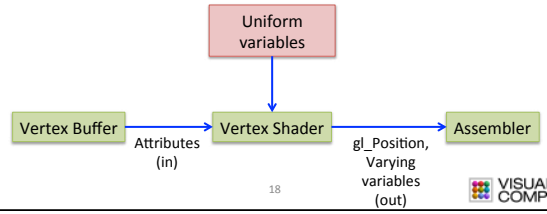
```
uniform float uVertexTemp;

attribute vec2 aPosition;
attribute vec3 aColor;

varying vec3 vColor;

void main() {
  gl_Position = vec4(aPosition.x, aPosition.y, 0,1);
  vColor = aColor;
}
```



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Fragment Shader

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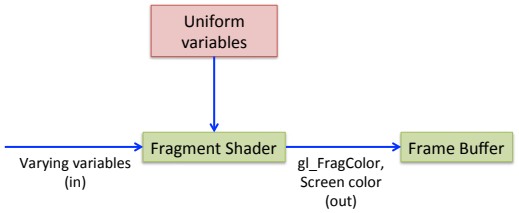
- Final pixel colors on the screen are determined in the fragment shader



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Fragment Shader

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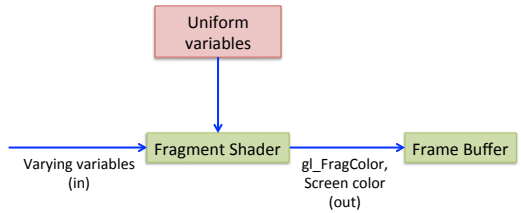
```
uniform float uColorTemp;

varying vec3 vColor;

void main(void) {
  vec4 color = vec4(vColor.x, vColor.y, vColor.z, 1);
  gl_FragColor = color;
}
```



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Exercise: Draw the First Polygon

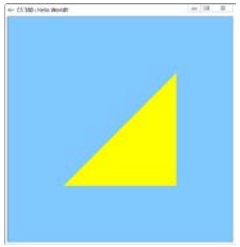
- Vertices are stored in a vertex buffer
- Positions, color and other attributes

```
struct SquareGeometry {
      static GLfloat sqPos[6 * 2] = {
            -0.5,  -0.5,
            0.5,  0.5,
            0.5, -0.5
        };

      static GLfloat sqCol[6 * 3] =  {
            1, 1, 0,
            1, 1, 0,
            1, 1, 0
      };
      ..
}
```

Vertex positions (x, y) of the triangle

Colors (R,G,B) of the triangle



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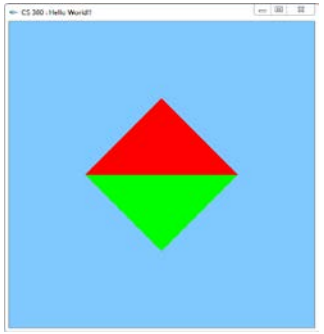
Exercise: Draw Your Own Polygon

e.g.)



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Exercise: Keyboard Input

- Callback functions are provided
- Add the following code into the 'keyboard' function

```
void keyboard(unsigned char key, int x, int y) {
  switch (key) {
  case 'h':
    cout << "Welcome to OpenGL World!\n " << " Please enjoy your self!\n
\n ";
   break;
  }
  glutPostRedisplay();
}
```


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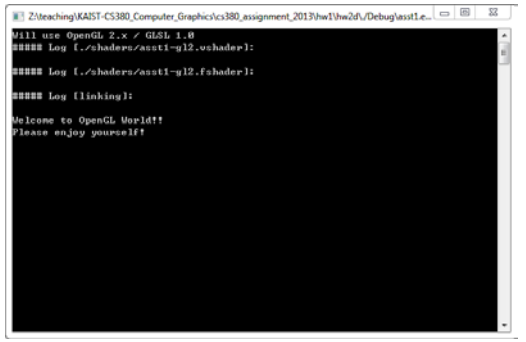
Keyboard Input



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Mouse Input

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- Callback function are provided
- Add the code into the 'mouse' function

```
static void mouse(int button, int state, int x, int y) {
 if (button == GLUT_LEFT_BUTTON) {
  if (state == GLUT_DOWN) {
     cout << "Mouse Left Button has been Clicked\n";
  }
  else {
     cout << "Mouse Left Button has been Released\n";
  }
 }
glutPostRedisplay();
}
```


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Mouse Input

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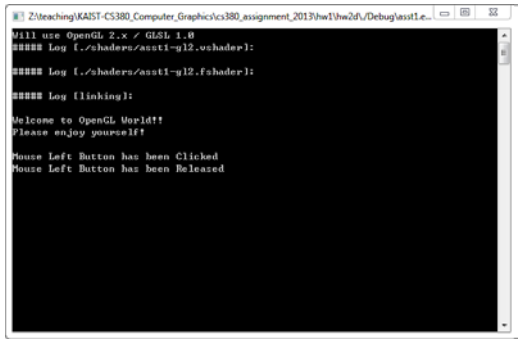

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Exercise

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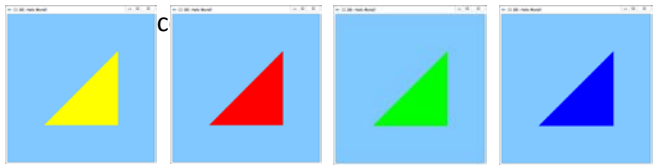
YOU SHOULD MODIFY THE SHADER FILE

- If you press 'r', 'g' or 'b', the color of the polygon should be changed to red, green or blue.
- Then, if you click 'p', the color should be returned to



original r g b

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Exercise

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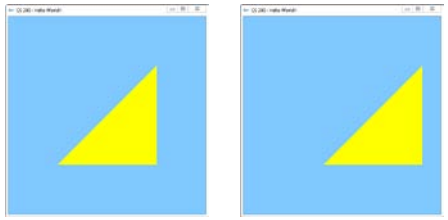
- If you click the 'mouse left or right button', then a polygon should move to left or right.



original right

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Hint

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- In vertex shader, we can determine the final positions of vertices
- In fragment shader, we can determine the final colors of vertices
- You should modify the uniform variables provided in the shader file

```
static float g_vertexTemp  = 0.0;      // for vertex moving
static float g_colorTemp   = 0.0;      // for changing color
```


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