

---

# OpenGL Shading Language (GLSL)

Sang Il Park  
Dept. of Software

---

# **A First Program: Many points with GPU**

# Setting for the most current opengl version for your computer

```
int main(int argc, char ** argv)
{
    glutInit(&argc, argv);
    glutInitDisplayMode(GLUT_SINGLE|GLUT_RGBA);
    glutInitWindowSize(512,512);
    glutCreateWindow("Many Points GPU");

    glewExperimental = true;
    glewInit();

    printf("OpenGL %s, GLSL %s\n",
        glGetString(GL_VERSION),
        glGetString(GL_SHADING_LANGUAGE_VERSION));

    glutDisplayFunc(display);
    glutMainLoop();

    return 0;
}
```

For using the  
modern OpenGL

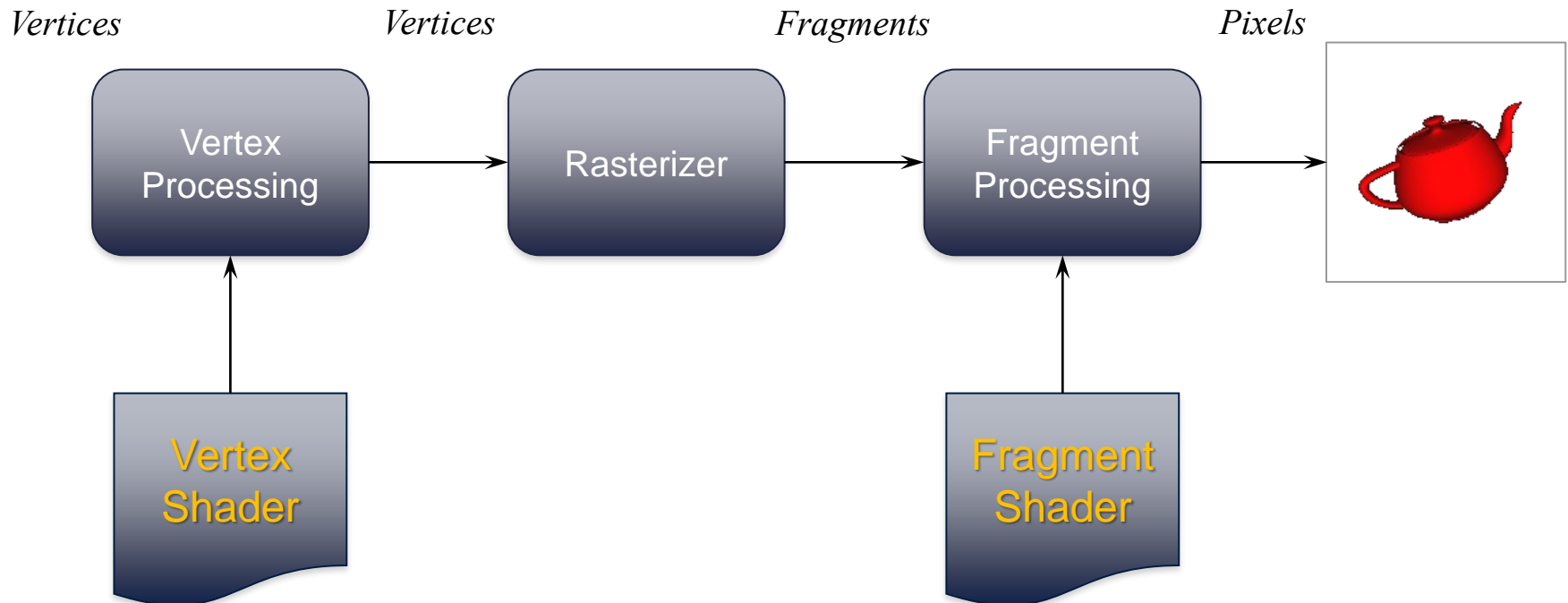
**glewExperimental = true;**  
**glewInit();**

To check the  
Current version

printf("OpenGL %s, GLSL %s\n",  
 glGetString(GL\_VERSION),  
 glGetString(GL\_SHADING\_LANGUAGE\_VERSION));

# OpenGL Pipeline (Simplified)

---



# OpenGL Programming in a Nutshell

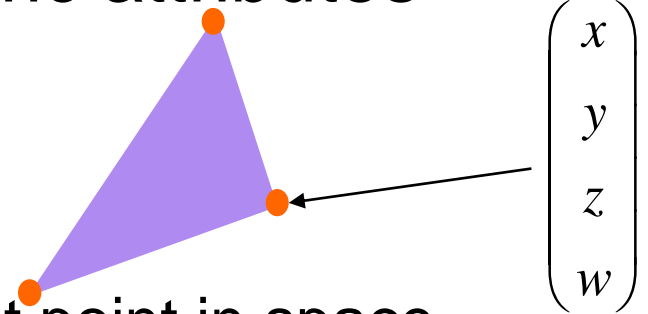
---

- Modern OpenGL programs essentially do the following steps:
  1. Create buffer objects and load data into them
  2. Create shader programs
  3. “Connect” data locations with shader variables
  4. Render

# Representing Geometric Objects

---

- Geometric objects are represented using vertices
- A vertex is a collection of generic attributes
  - positional coordinates
  - colors
  - texture coordinates
  - any other data associated with that point in space
- Position stored in 4 dimensional homogeneous coordinates



- Vertex data must be stored in *vertex buffer objects* (**VBOs**)
- VBOs must be stored in *vertex array objects* (**VAOs**)

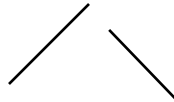
# OpenGL's Geometric Primitives

---

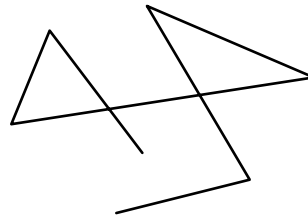
- All primitives are specified by vertices



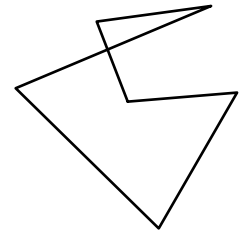
**GL\_POINTS**



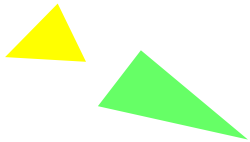
**GL\_LINES**



**GL\_LINE\_STRIP**



**GL\_LINE\_LOOP**



**GL\_TRIANGLES**



**GL\_TRIANGLE\_STRIP**



**GL\_TRIANGLE\_FAN**

# Creating Data

---

- Define an array for storing all the points

```
struct vec2
{
    float x;
    float y;
};

const int NumPoints = 5000;

void init()
{
    vec2 points[NumPoints];

    for ( int i = 0; i < NumPoints; i++ )
    {
        points[i].x = (rand()%200)/100.0f-1.0f;
        points[i].y = (rand()%200)/100.0f-1.0f;
    }
}
```



# Draw the array at once

---

- Define an array for storing all the points

```
void display()
{
    glClear(GL_COLOR_BUFFER_BIT);
    glDrawArrays(GL_POINTS, 0, NumPoints);
}
```

Above code draws the data in GPU.  
But we didn't send the data to GPU at all!!

# How to send your data

---

- Vertex data must be stored in *vertex buffer objects* (**VBOs**)
- VBOs must be stored in *vertex array objects* (**VAOs**)

# How to send your data

---

Generate a Vertex Array

`glGenVertexArray(...)`



Bind the Vertex Array

`glBindVertexArray(...)`



Generate a Buffer Object

`glGenBuffers(...)`



Bind the Buffer Object

`glBindBuffer(...)`



Set the Buffer Object data

`glBufferData(...)`

# Vertex Array Objects (VAOs)

---

- VAOs store the data of a geometric object
- Steps in using a VAO
  - generate VAO names by calling `glGenVertexArrays()`
  - bind a specific VAO for initialization by calling `glBindVertexArray()`
  - update VBOs associated with this VAO
  - bind VAO for use in rendering
- This approach allows a single function call to specify all the data for an objects
  - previously, you might have needed to make many calls to make all the data current

# VAOs in Code

---

```
// Create a vertex array object  
GLuint vao;  
glGenVertexArrays(1, &vao);  
glBindVertexArray(vao);
```

# Storing Vertex Attributes

---

- Vertex data must be stored in a VBO, and associated with a VAO
- The code-flow is similar to configuring a VAO
  - generate VBO names by calling `glGenBuffers()`
  - bind a specific VBO for initialization by calling `glBindBuffer(GL_ARRAY_BUFFER, ...)`
  - load data into VBO using `glBufferData(GL_ARRAY_BUFFER, ...)`
  - bind VAO for use in rendering later `glBindVertexArray()`

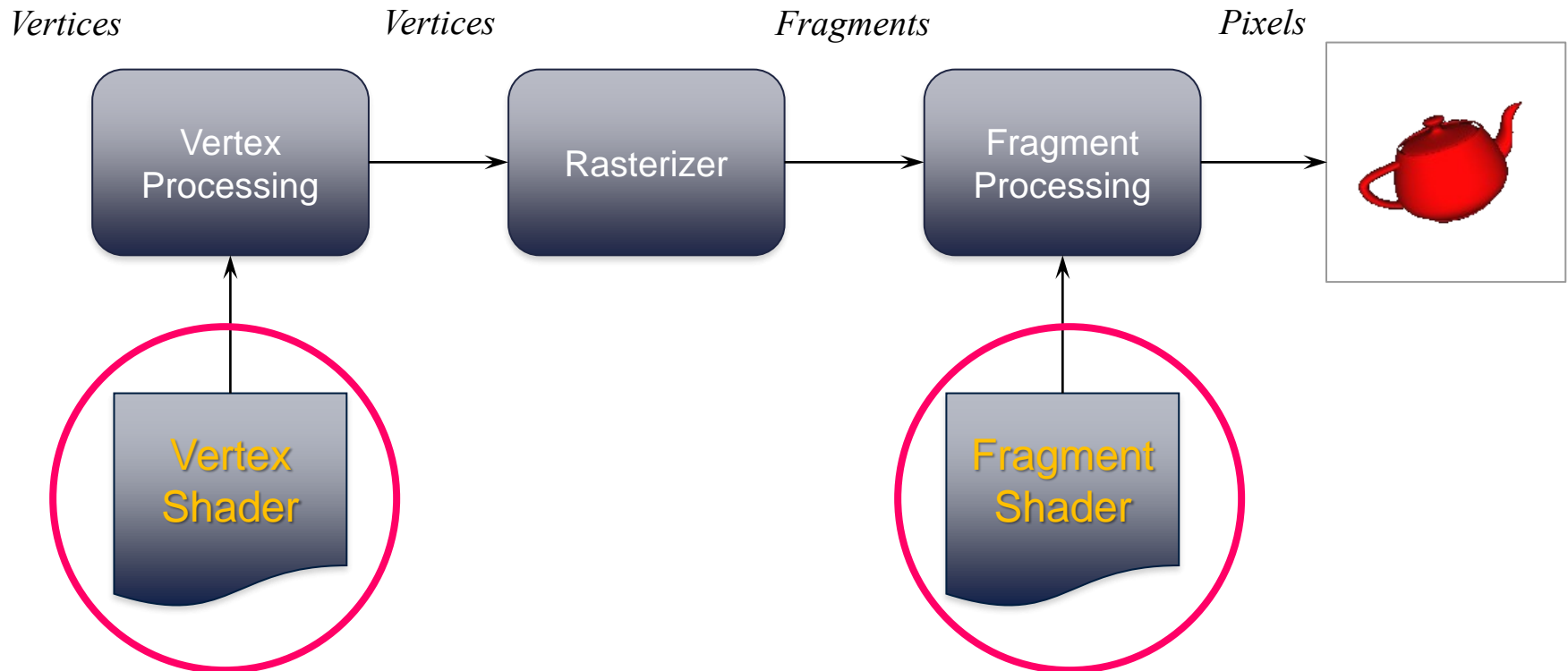
# VBOs in Code

---

```
// Create and initialize a buffer object
GLuint buffer;
glGenBuffers(1, &buffer);
glBindBuffer(GL_ARRAY_BUFFER, buffer);
glBufferData(GL_ARRAY_BUFFER, sizeof(points),
             points, GL_STATIC_DRAW);
```

# We need shaders before drawing

---





# Vertex Shader Code (vshader.glsl)

---

```
#version 330

in vec4 vPosition;

void main()
{
    gl_Position = vPosition;
}
```

# Fragment Shader Code (fshader.glsl)

---

```
#version 330

out vec4 fColor;

void main()
{
    fColor = vec4(1.0,0.0,0.0,1.0);
}
```

# Loading Shaders

---

```
#include <InitShader.h>
```

```
// Load and use shaders
```

```
GLuint program
```

```
    = InitShader( "vshader.glsl", "fshader.glsl" );
```

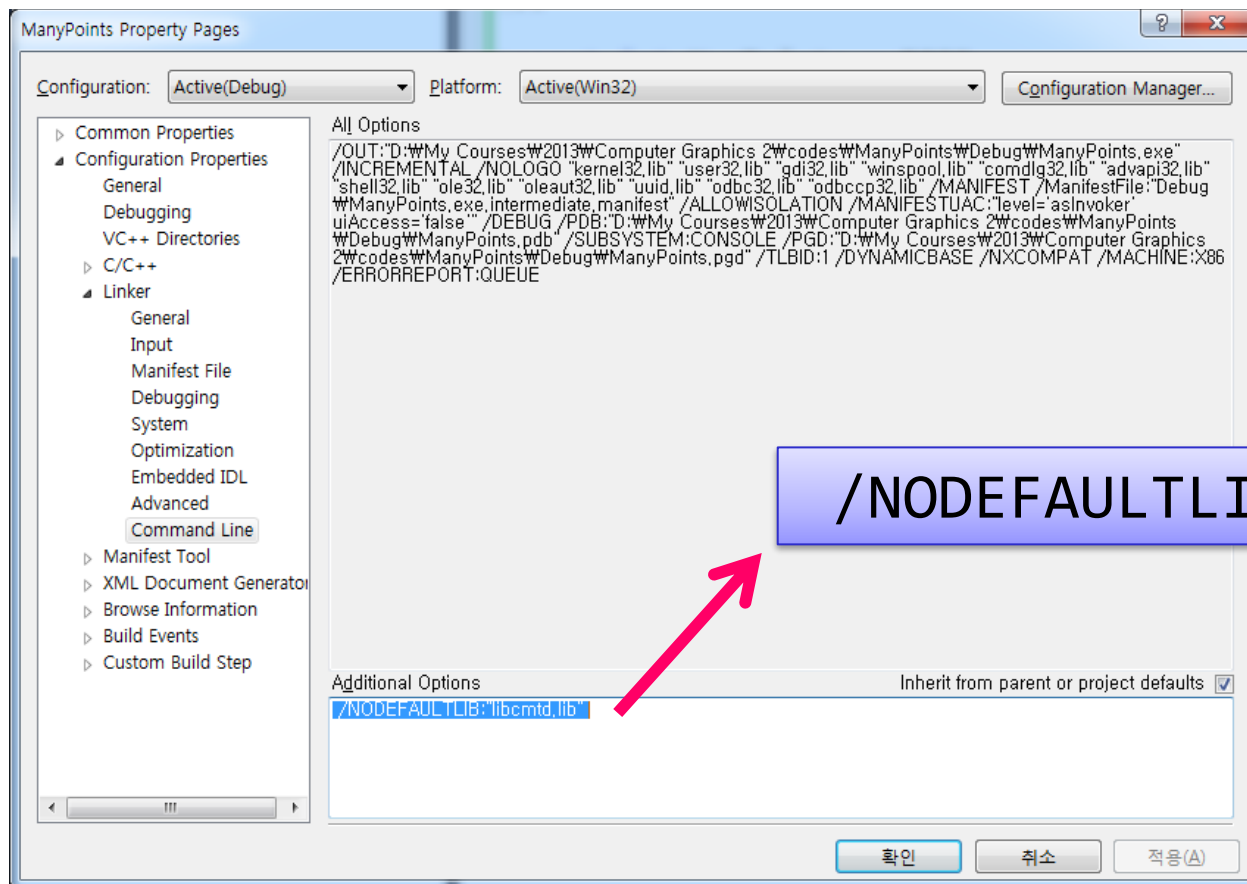
```
glUseProgram( program );
```

glsl : opengl shader language

Those are provided in our homepage.

# If you see an error: You should change Project Setting

- Conflict with an existing lib “libcmt.lib”:



# Connecting Vertex Shaders with Geometry

---

- Application vertex data enters the OpenGL pipeline through the vertex shader
- Need to connect vertex data to shader variables
  - requires knowing the attribute location
- Attribute location can either be queried by calling `glGetVertexAttribLocation()`

# Vertex Array Code

---

```
// set up vertex arrays (after shaders are loaded)
int vPosition = 0;
glEnableVertexAttribArray( vPosition );
glVertexAttribPointer( vPosition, 2, GL_FLOAT,
                      GL_FALSE, 0, BUFFER_OFFSET(0) );
```

# Drawing Geometric Primitives

---

- For contiguous groups of vertices

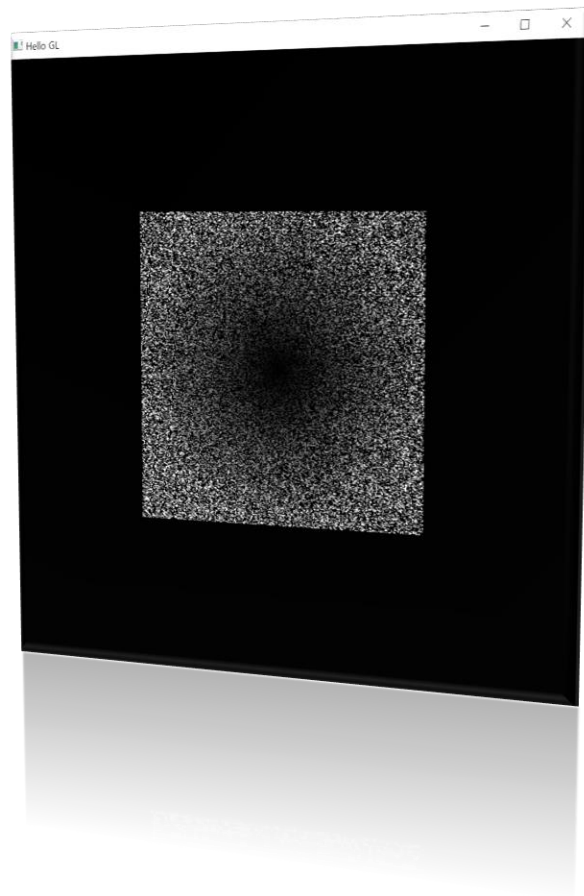
```
glDrawArrays(GL_POINTS, 0, NumPoints);
```

- Usually invoked in display callback
- Initiates vertex shader

# Summary

---

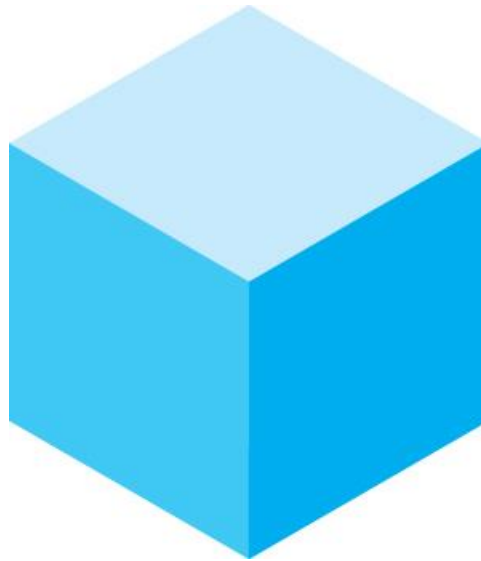
- Setting for libraries
  - Set include/lib folder
  - `#include <vgl.h>`
  - `#include <initshader.h>`
- Creating data(in an array form)
- Sending the data
  - VAO – vertex array object
  - VBO – vertex buffer object
- Loading the shaders
- Draw it with `glDrawArrays(...)`





---

# A Color Cube example



# Rendering a Cube

---

- We'll render a cube with colors at each vertex
- Our example demonstrates:
  - initializing vertex data
  - organizing data for rendering
  - simple object modeling
    - building up 3D objects from geometric primitives
    - building geometric primitives from vertices

# Initializing the Cube's Data

---

- We'll build each cube face from individual triangles
- Need to determine how much storage is required
  - (6 faces)(2 triangles/face)(3 vertices/triangle)  
`const int NumVertices = 36;`
- To simplify communicating with GLSL, we'll use a vec4 class (implemented in C++) similar to GLSL's vec4 type

```
#include <vec.h>
```

# Initializing the Cube's Data (cont'd)

---

- Before we can initialize our VBO, we need to stage the data
- Our cube has two attributes per vertex
  - position
  - color
- We create two arrays to hold the VBO data

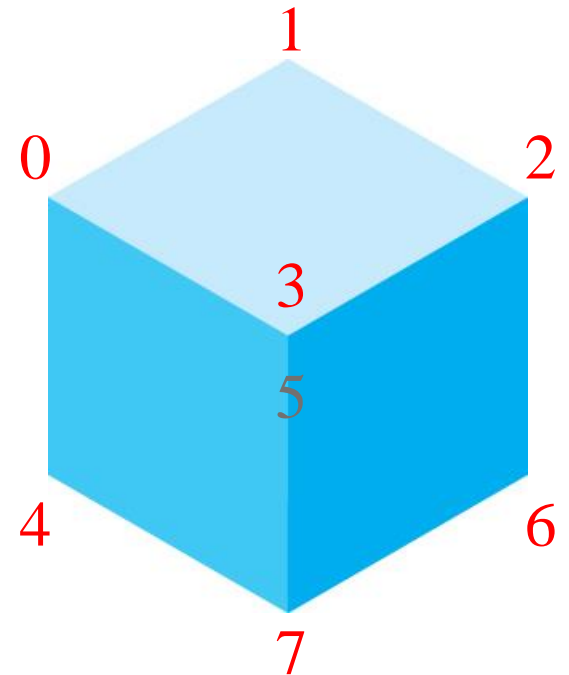
```
vec4  points[NumVertices];  
vec4  colors[NumVertices];
```

# Cube Data

---

// Vertices of a unit cube centered at origin, sides aligned with axes

```
vec4 vertex_pos [8] = {  
    vec4 ( -0.5, -0.5,  0.5, 1.0 ),  
    vec4 ( -0.5,  0.5,  0.5, 1.0 ),  
    vec4 (  0.5,  0.5,  0.5, 1.0 ),  
    vec4 (  0.5, -0.5,  0.5, 1.0 ),  
    vec4 ( -0.5, -0.5, -0.5, 1.0 ),  
    vec4 ( -0.5,  0.5, -0.5, 1.0 ),  
    vec4 (  0.5,  0.5, -0.5, 1.0 ),  
    vec4 (  0.5, -0.5, -0.5, 1.0 )  
};
```



# Cube Data

---

```
// RGBA colors
```

```
vec4 vertex_colors[8] = {  
    vec4 ( 0.0, 0.0, 0.0, 1.0 ), // black  
    vec4 ( 1.0, 0.0, 0.0, 1.0 ), // red  
    vec4 ( 1.0, 1.0, 0.0, 1.0 ), // yellow  
    vec4 ( 0.0, 1.0, 0.0, 1.0 ), // green  
    vec4 ( 0.0, 0.0, 1.0, 1.0 ), // blue  
    vec4 ( 1.0, 0.0, 1.0, 1.0 ), // magenta  
    vec4 ( 1.0, 1.0, 1.0, 1.0 ), // white  
    vec4 ( 0.0, 1.0, 1.0, 1.0 ) // cyan  
};
```

# Generating a Cube Face from Vertices

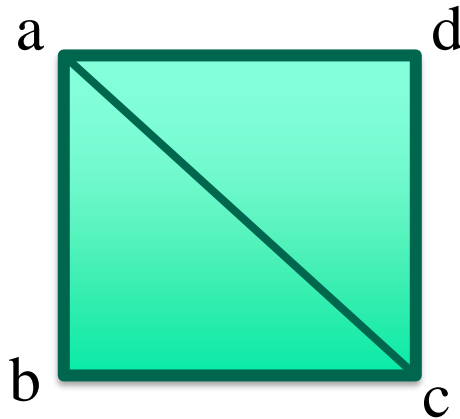
---

```
// quad() generates two triangles for each face and assigns colors to the
// vertices

int Index = 0; // global variable indexing into VBO arrays

void quad(int a, int b, int c, int d) {
    colors[Index] = vertex_colors[a]; points[Index] = vertex_pos[a]; Index++;
    colors[Index] = vertex_colors[b]; points[Index] = vertex_pos[b]; Index++;
    colors[Index] = vertex_colors[c]; points[Index] = vertex_pos[c]; Index++;

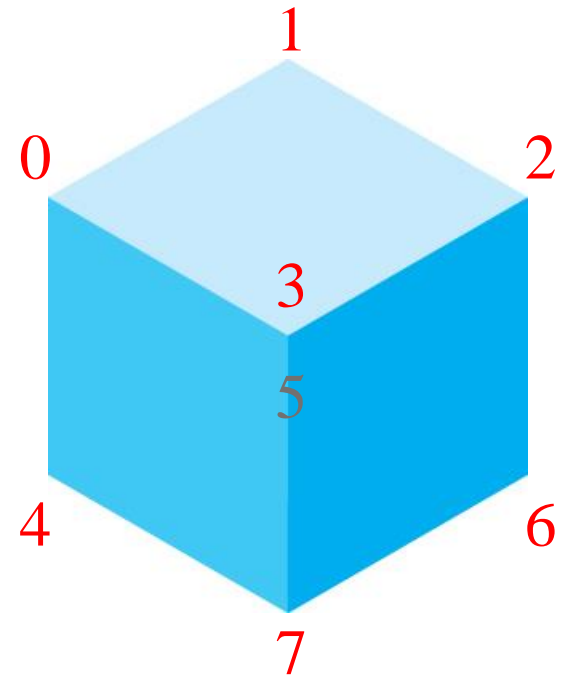
    colors[Index] = vertex_colors[a]; points[Index] = vertex_pos[a]; Index++;
    colors[Index] = vertex_colors[c]; points[Index] = vertex_pos[c]; Index++;
    colors[Index] = vertex_colors[d]; points[Index] = vertex_pos[d]; Index++;
}
```



# Generating the Cube from Faces

---

```
// generate 12 triangles: 36 vertices and 36
  colors
void
colorcube() {
    quad( 1, 0, 3, 2 );
    quad( 2, 3, 7, 6 );
    quad( 3, 0, 4, 7 );
    quad( 6, 5, 1, 2 );
    quad( 4, 5, 6, 7 );
    quad( 5, 4, 0, 1 );
}
```





# Vertex Array Objects (VAOs)

---

- VAOs store the data of a geometric object
- Steps in using a VAO
  - generate VAO names by calling `glGenVertexArrays()`
  - bind a specific VAO for initialization by calling `glBindVertexArray()`
  - update VBOs associated with this VAO
  - bind VAO for use in rendering
- This approach allows a single function call to specify all the data for an objects
  - previously, you might have needed to make many calls to make all the data current

# VAOs in Code

---

```
// Create a vertex array object
GLuint vao;
glGenVertexArrays(1, &vao);
glBindVertexArray(vao);
```

# Storing Vertex Attributes

---

- Vertex data must be stored in a VBO, and associated with a VAO
- The code-flow is similar to configuring a VAO
  - generate VBO names by calling `glGenBuffers()`
  - bind a specific VBO for initialization by calling `glBindBuffer(GL_ARRAY_BUFFER, ...)`
  - load data into VBO using `glBufferData(GL_ARRAY_BUFFER, ...)`
  - bind VAO for use in rendering `glBindVertexArray()`

# VBOs in Code

---

```
// Create and initialize a buffer object
GLuint buffer;
glGenBuffers(1, &buffer);
glBindBuffer(GL_ARRAY_BUFFER, buffer);
glBufferData(GL_ARRAY_BUFFER, sizeof(points) +
             sizeof(colors), NULL, GL_STATIC_DRAW);

glBufferSubData(GL_ARRAY_BUFFER, 0, sizeof(points), points);
glBufferSubData(GL_ARRAY_BUFFER, sizeof(points),
               sizeof(colors), colors);
```

# Loading Shaders

---

```
#include <InitShader.h>
```

```
// Load and use shaders
```

```
GLuint program
```

```
    = InitShader( "vshader.glsl", "fshader.glsl" );
```

```
glUseProgram( program );
```

glsl : opengl shader language

Those are provided in our homepage.

# Connecting Vertex Shaders with Geometry

---

- Application vertex data enters the OpenGL pipeline through the vertex shader
- Need to connect vertex data to shader variables
  - requires knowing the attribute location
- Attribute location can either be queried by calling `glGetVertexAttribLocation()`

# Vertex Array Code

---

```
// set up vertex arrays (after shaders are loaded)
GLuint vPosition = glGetAttribLocation(program, "vPosition");
glEnableVertexAttribArray(vPosition);
glVertexAttribPointer(vPosition, 4, GL_FLOAT, GL_FALSE, 0,
    BUFFER_OFFSET(0));
```

```
GLuint vColor = glGetAttribLocation(program, "vColor");
glEnableVertexAttribArray(vColor);
glVertexAttribPointer(vColor, 4, GL_FLOAT, GL_FALSE, 0,
    BUFFER_OFFSET(sizeof(points)));
```

# Drawing Geometric Primitives

---

- For contiguous groups of vertices

```
glDrawArrays(GL_TRIANGLES, 0, NumVertices);
```

- Usually invoked in display callback
- Initiates vertex shader



# Summary

---

- We learnt the very basic of defining geometry and use it on GPU
- Today, we will learn how to code the shaders
- ***Vertex Shader :***
  - Determining the positions of vertex
  - Useful for scaling, rotating, deforming and so on.
  - Also important for preparing some information sending to Fragment Shader
- ***Fragment Shader :***
  - Determining the color of each fragment

