Programming with OpenGL
Part 5: More GLSL

CS 432 Interactive Computer Graphics

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Objectives

- Coupling shaders to applications
  - Reading
  - Compiling
  - Linking
- Vertex Attributes
- Setting up uniform variables
- Example applications

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Linking Shaders with Application

- Read shaders
- Compile shaders
- Create a program object
- Link everything together
- Link variables in application with variables in shaders
  - Vertex attributes
  - Uniform variables

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Reading a Shader

- Shaders are added to the program object and compiled
- Usual method of passing a shader is as a null-terminated string using the function
- gl.shaderSource(fragShdr, fragElem.text);
- If shader is in HTML file, we can get it into application by getElementById method
- If the shader is in a file, we can write a reader to convert the file to a string

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Adding a Vertex Shader

```
var vertShdr;
var vertElem =
   document.getElementById( vertexShaderId );

vertShdr = gl.createShader( gl.VERTEX_SHADER );

gl.shaderSource( vertShdr, vertElem.text );
gl.compileShader( vertShdr );

// after program object created
gl.attachShader( program, vertShdr );
```


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Adding a Fragment Shader

```
var fragShdr;
var fragElem =
   document.getElementById( fragmentShaderId );

fragShdr = gl.createShader( gl.FRAGMENT_SHADER );

gl.shaderSource( fragShdr, fragElem.text );
gl.compileShader( fragShdr );

// after program object created
gl.attachShader( program, fragShdr );
```


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Shader File Reader

- Following code may be a security issue with some browsers if run locally

```
function getShader(gl, shaderName, type) {
        var shader = gl.createShader(type);
        shaderScript = loadFileAJAX(shaderName);
        if (!shaderScript) {
            alert("Could not find shader source:
                    "+shaderName);
        }
}
```


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Program Object

- Container for shaders
  - Can contain multiple shaders
  - Other GLSL functions

```
var program = gl.createProgram();

gl.attachShader( program, vertShdr );
gl.attachShader( program, fragShdr );
gl.linkProgram( program );
```

`Go to initShaders.js`

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Attribute and Varying Qualifiers

- Starting with OpenGL GLSL 1.4 *attribute* and *varying* qualifiers have been replaced by *in* and *out* qualifiers
- No changes needed in application
- Vertex shader example:

```
# WebGL version 1.0
# GLSL ES version 1.0
# GLSL version 1.2
attribute vec3 vPosition;
varying vec3 color;
```

```
# WebGL version 2.0
# GLSL ES version 3.0
# GLSL version 1.4
in vec3 aPosition;
out vec3 vColor;
```


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Vertex Attributes

- Vertex attributes are named in the shaders
- Linker forms a table
- Application can get index from table and ties it to an application variable
- Similar process for uniform variables

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Adding Color

- If we set a color in the application, we can send it to the shaders as a per vertex attribute or as a uniform variable depending on how often it changes
- Let's associate a color with each vertex
- Set up an array of same size as positions
- Send to GPU as a buffer object

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Sending Vertices from Application

```
var vBuffer = gl.createBuffer();
gl.bindBuffer( gl.ARRAY_BUFFER, vBuffer );
gl.bufferData( gl.ARRAY_BUFFER, flatten(vertices),
                gl.STATIC_DRAW );

var aPosition = gl.getAttribLocation( program, "aPosition" );
gl.vertexAttribPointer( aPosition, 3, gl.FLOAT, false, 0, 0 );
gl.enableVertexAttribArray( aPosition );
```


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Sending Colors from Application

```
var cBuffer = gl.createBuffer();
gl.bindBuffer( gl.ARRAY_BUFFER, cBuffer );
gl.bufferData( gl.ARRAY_BUFFER, flatten(colors),
                    gl.STATIC_DRAW );

var aColor = gl.getAttribLocation( program, "aColor" );
gl.vertexAttribPointer( aColor, 3, gl.FLOAT, false, 0, 0 );
gl.enableVertexAttribArray( aColor );
```


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Sending a Uniform Variable

```
// in application
vec4 color = vec4(1.0, 0.0, 0.0, 1.0);
colorLoc = gl.getUniformLocation( program, "color" );
gl.uniform4fv( colorLoc, color );


// in fragment shader (similar in vertex shader)
uniform vec4 color;
out vec4 fcolor;
void main()
{
   fColor = color;
}
```


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Coloring Each Vertex (New)

```
in vec3 aPosition, aColor;
out vec3 vColor;

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


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Coloring Each Fragment (New)

```
precision highp float;
in vec3 vColor;
out vec4 fColor;

void main()
{
  fColor = vec4(vColor, 1);
}
```


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Drawing Data in Buffers

```
function render() {

  gl.clear( gl.COLOR_BUFFER_BIT );
  gl.drawArrays( gl.TRIANGLE_FAN, 0, 4 );

}
```


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Review Code

```
Go to HW2.html
      HW2.js
      MV.js
```


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Programming with WebGL
Part 6: Going to Three Dimensions

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Objectives

- Develop a more sophisticated three-dimensional example
  - Sierpinski gasket: a fractal
- Introduce hidden-surface removal

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Three-dimensional Applications

- In Open/WebGL, two-dimensional applications are a special case of three-dimensional graphics
- Going to 3D
  - Not much changes
  - Use `vec3, gl.uniform3f`
  - Have to worry about the order in which primitives are rendered or use hidden-surface removal

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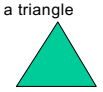
Sierpinski Gasket (2D)

- Start with a triangle



- Connect bisectors of sides and remove central triangle

- Repeat

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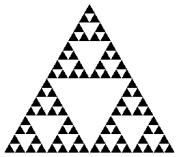
Example

- Five subdivisions



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The gasket as a fractal

- Consider the filled area (black) and the perimeter (the length of all the lines around the filled triangles)
- As we continue subdividing
  - the area goes to zero
  - but the perimeter goes to infinity
- This is not an ordinary geometric object
  - It is neither two- nor three-dimensional
- It is a *fractal* (fractional dimension) object

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Gasket Program

- HTML file
  - Same as in other examples
  - Pass through vertex shader
  - Fragment shader sets color
  - Read in JS file

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Gasket Program

```
var points = [];
var NumTimesToSubdivide = 5;

/* initial triangle */

 var vertices = [
        vec2( -1, -1 ),
        vec2(  0,  1 ),
        vec2(  1, -1 )
    ];

divideTriangle( vertices[0],vertices[1],
     vertices[2], NumTimesToSubdivide);
```


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Draw one triangle

```
/* display one triangle  */

function triangle( a, b, c ){
    points.push( a, b, c );
}
```


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Triangle Subdivision

```
function divideTriangle( a, b, c, count ){
 // check for end of recursion
    if ( count === 0 ) {
    triangle( a, b, c );
    }
    else {
//bisect the sides
    var ab = mix( a, b, 0.5 );
    var ac = mix( a, c, 0.5 );
    var bc = mix( b, c, 0.5 );
    --count;
// three new triangles
    divideTriangle( a, ab, ac, count-1 );
    divideTriangle( c, ac, bc, count-1 );
    divideTriangle( b, bc, ab, count-1 );
    }
}
```


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init()

```
var program = initShaders(gl, "vertex-shader",
                          "fragment-shader");
gl.useProgram( program );
var bufferId = gl.createBuffer();
gl.bindBuffer( gl.ARRAY_BUFFER, bufferId );
gl.bufferData(gl.ARRAY_BUFFER, flatten(points),
                               gl.STATIC_DRAW );
var aPosition = gl.getAttribLocation( program,
                               "aPosition" );
gl.vertexAttribPointer( aPosition, 2, gl.FLOAT,
                                false, 0, 0 );
gl.enableVertexAttribArray( aPosition );
render();
```


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Render Function

```
function render(){

  gl.clear( gl.COLOR_BUFFER_BIT );

  gl.drawArrays( gl.TRIANGLES, 0,
                           points.length );
}
```


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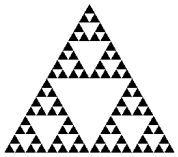
Example

- Five subdivisions



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Moving to 3D

- We can easily make the program three-dimensional by using

```
point3 v[3]
```

and we start with a tetrahedron

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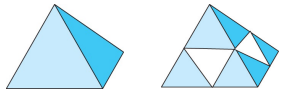
3D Gasket

- We can subdivide each of the four faces



- Appears as if we remove a solid tetrahedron from the center leaving four smaller tetrahedra
- Code almost identical to 2D example

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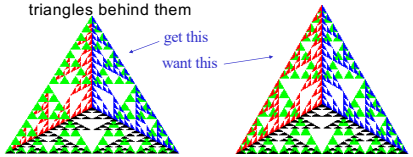
Almost Correct

- Because the triangles are drawn in the order they are specified in the program, the front triangles are not always rendered in front of triangles behind them



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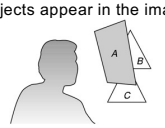
Hidden-Surface Removal

- We want to see only those surfaces in front of other surfaces
- Open/WebGL uses a *hidden-surface* method called the z-buffer algorithm that saves depth information as objects are rendered so that only the front objects appear in the image



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Z-buffering

- Z-buffering (depth-buffering) is a visible surface detection algorithm
- Implementable in hardware and software
- Requires data structure (z-buffer) in addition to frame buffer.
- Z-buffer stores values [0 .. ZMAX] corresponding to depth of each point.
- If the point is closer than one in the buffers, it will replace the buffered values

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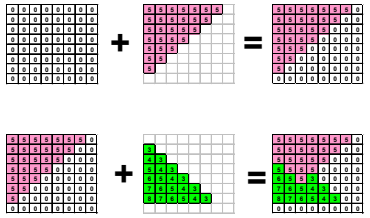
Z-buffering



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Z-buffering w/ front/back clipping

```
for (y = 0; y < YMAX; y++)
  for (x = 0; x < XMAX; x++) {
        F[x][y] = BACKGROUND_VALUE;
        Z[x][y] = -1;  /* Back value in NPC */
  }
for (each polygon)
  for (each pixel in polygon's projection) {
        pz = polygon's z-value at pixel coordinates (x,y)
        if (pz < FRONT && pz > Z[x][y]) {  /* New point is behind front
                                              plane & closer than previous point */
              Z[x][y] = pz;
              F[x][y] = polygon's color at pixel coordinates (x,y)
        }
  }
```

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Using the *z*-buffer algorithm

- The algorithm uses an extra buffer, the z-buffer, to store depth information as geometry travels down the pipeline
- Depth buffer is required to be available in WebGL
- It must be
  - Enabled
    - `gl.enable(gl.DEPTH_TEST)`
  - Cleared in for each render
    - `gl.clear(gl.COLOR_BUFFER_BIT | gl.DEPTH_BUFFER_BIT)`

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Surface vs Volume Subdvision

- In our example, we divided the surface of each face
- We could also divide the volume using the same midpoints
- The midpoints define four smaller tetrahedrons, one for each vertex
- Keeping only these tetrahedrons removes a *volume* in the middle
- See text for code

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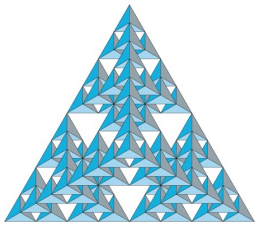
Volume Subdivision



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Swapping Shader Programs

- May need different shader programs for different objects or situations in a graphics application
- Could pass a flag to one set of shader programs to execute different code for different objects or situations
- This strategy might produce performance degradation
- Alternative: Dynamically change shader programs

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Swapping Shader Programs

During initialization

- Create shaders

```
program1_ID = initShaders(gl, "vertex_shader1", "fr
program2_ID = initShaders(gl, "vertex_shader2", "fr
```

- Get locations of uniform and attrib variables

```
thetaLoc1      = gl.getUniformLocation(program1
positionLoc1 = gl.getAttribLocation(program1_ID

thetaLoc2      = gl.getUniformLocation(program2
positionLoc2 = gl.getAttribLocation(program2_ID
```

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Swapping Shader Programs

During initialization

- Create and fill buffers

```
positionBuffer1 = gl.createBuffer();
gl.bindBuffer(gl.ARRAY_BUFFER, positionBuffer1);
gl.bufferData(gl.ARRAY_BUFFER, flatten(positions1), g

positionBuffer2 = gl.createBuffer();
gl.bindBuffer(gl.ARRAY_BUFFER, positionBuffer2);
gl.bufferData(gl.ARRAY_BUFFER, flatten(positions2), g
```

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Swapping Shader Programs

In the render() function

- Use first shader program

```
gl.useProgram(program1_ID);
```

- Set uniform value

```
gl.uniform1f(thetaLoc1, rotateAngle1);
```

- Bind a buffer and define its attributes

```
gl.bindBuffer(gl.ARRAY_BUFFER, positionBuffer1);
gl.vertexAttribPointer(positionLoc1, 2, gl.FLOAT, fa
gl.enableVertexAttribArray(positionLoc1);
```

- Draw data in the buffer

```
gl.drawArrays(gl.TRIANGLE_FAN, 0, numOfVertices1);
```

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Swapping Shader Programs

In the render() function

- Use second shader program

```
gl.useProgram(program2_ID);
```

- Set uniform value

```
gl.uniform1f(thetaLoc2, rotateAngle2);
```

- Bind a buffer and define its attributes

```
gl.bindBuffer(gl.ARRAY_BUFFER, positionBuffer2);
gl.vertexAttribPointer(positionLoc2, 2, gl.FLOAT, fa
gl.enableVertexAttribArray(positionLoc2);
```

- Draw data in the buffer

```
gl.drawArrays(gl.TRIANGLE_FAN, 0, numOfVertices2);
```

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