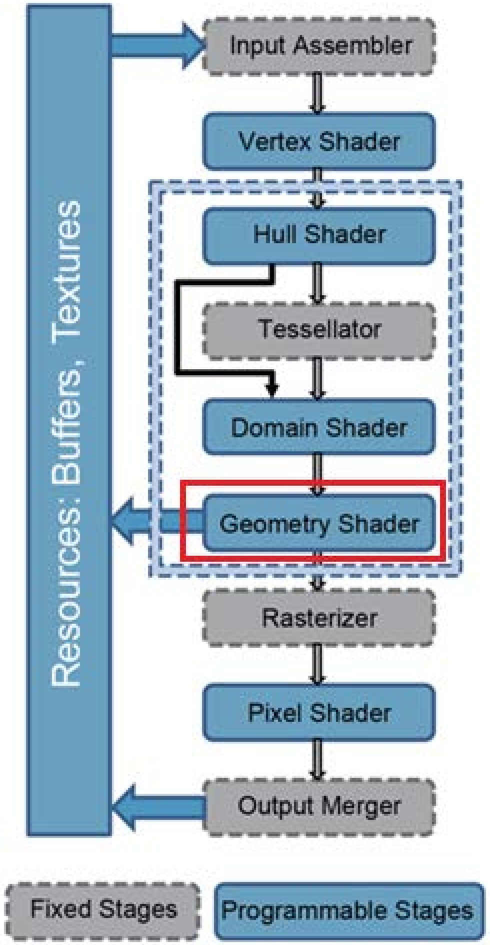
Geometry Shader

Geometry Shader

- The Geometry Shader is an optional stage that sits between vertex shader and fragment shader.
- The vertex shader input vertices the geometry shader inputs geometries (points, trianles, polygons)
- The main advantage of GS is they can create or destroy complete geometries

Geometry Shader



Geometry Shaders

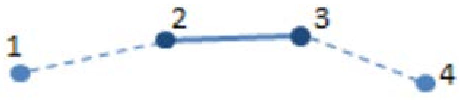
- So one primitive can be expanded into other premitive types.
- Points can be converted to triangles.
- And triangles into many triangles.

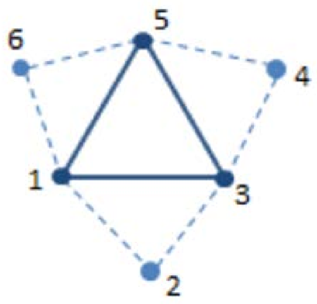
Primitive Types

- The available geometry shader input primitives are:
  - points (1)
  - lines (2)
  - triangles (3)
  - lines_adjacency (4)
  - triangles_adjacency (6)

Primitive Types

- while primitives without adjacency contain only the vertices of the target primitive.
- Primitives with adjacency contain some of the surrounding vertices, Lines Adjacency, Triangles Adjacency





Data Types

- gl_InvocationID — contains the invocation index of the current shader.
- It is assigned an integer value in the range [0, N-1] where N is the number of geometry shader invocations per primitive
- Identifies the invocation number assigned to the geometry shader invocation.

Built In Data Types

- Built in struct

```
in gl_PerVertex {
  vec4 gl_Position;
  float gl_PointSize;
  float gl_ClipDistance[];
} gl_in[];
```

- Get information on a per vertex basis.
- Gets an **array** of information.

Built In Data Types

- gl_Position information is transferred from one shader stage to the next.
- For Example
  - Vertex Shader
    - layout (location = 0) in vec3 position;
    - gl_Position = vec4(position, 1.0f);
  - Geometry Shader
    - vec4 p1 = gl_in[0].gl_Position
- Then p1 will have same value as what was assigned into gl_Positon in vertex shader.
- In vertex shader if u multiply by mvp then p1 will be affected accordingly

Custom Data Types

```
out VS_GS_VERTEX{
    out vec4 position;
    out vec3 color;
    out mat4 mvp;
} vs_out;

void main(){

   gl_Position = mvp * vec4(position, 1.0f);

    vs_out.color = color;
    vs_out.position = gl_Position;
    vs_out.mvp = mvp;
}
```

Custom Data Types

```
in VS_GS_VERTEX{
    in vec4 position;
    in vec3 color;
    in mat4 mvp;
}gs_in[];
out vec3 outColor;
void main() {
    outColor = gs_in[0].color;
    gl_Position = gs_in[0].position + gs_in[0].mvp * vec4(-2.0f, 0.0f, 0.0f, 0.0f);
}
```

GS Special Properties - Instancing

- You can cause the GS to execute multiple times for the same input primitive.
- Each invocation of the GS for a particular input primitive will get a different **gl_InvocationID** value.
- This is useful for layered rendering and outputs to multiple streams.

```
layout(invocations = num_instances) in;
```

GS Special Properties - Ouput Streams

- GS's can send vertex data to one stream to fragment shader.
- While building per-instance data in another stream.
- Multiple stream **output** *requires* that the output primitive type be points.
- You can still take whatever input you prefer.

GS Special Properties - Output Streams

- output variables can be given a stream index with a layout qualifier
- layout(stream = stream_index) out vec4 some_output;
- The *stream_index* ranges from 0 to GL_MAX_VERTEX_STREAMS - 1
- A default value for the stream can be set
- layout(stream = 2) out;

Geometry Shaders

- The shader itself is a bit different from the vertex and fragment shader.
- The type of data being passed in must be specified in the geometry shader

  layout (points) in;
- Here we are passing in points but we could be passing in lines or triangles as well.

Geometry Shaders

- We also need to specify the type of primitive we want out of the shader.
- Also the maximum number of vertices being sent out should also be specified.

layout (triangle_strip, max_vertices = 3) out;

- **out** is a keyword which specifies the output type.
- Here we can be sending out *points* or *line_strip* instead.
- The max vertices being sent out is 3

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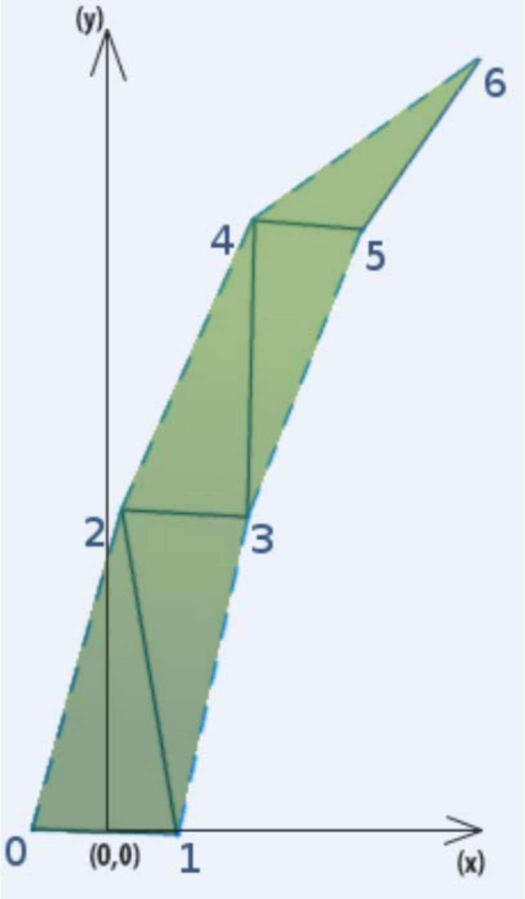
Geometry Shaders

- The new vertices are specified with respect to the objects local coordinates.
- gl_Position = gs_in[0].position + vec4(-2.0f, 0.0f, 0.0f, 0.0f);

Geometry Shaders



Geometry Shaders

- Every time a vertex is added **EmitVertex()** needs to be called as the vertex will be added to the primitive.

- Once the number of vertices is added to form the shape **EndPrimitive()** needs to be called to create the primitives from vertices added.

Vertex Shader

```
#version 430 core
layout (location = 0) in vec3 position;
layout (location = 1) in vec3 color;

out VS_GS_VERTEX{
    out vec4 position;
    out vec3 color;
    out mat4 mvp;
} vs_out;

uniform mat4 mvp;

void main(){

    gl_Position = mvp * vec4(position, 1.0f);

    vs_out.color = color;
    vs_out.position = gl_Position;
    vs_out.mvp = mvp;
}
```

Geometry Shader

```
#version 430 core
layout (points) in;
layout (triangle_strip, max_vertices = 3) out;

out vec3 outColor;

in VS_GS_VERTEX{
      in vec4 position;
      in vec3 color;
      in mat4 mvp;
}gs_in[];

void main() {

      outColor = gs_in[0].color;

      gl_Position = gs_in[0].position + gs_in[0].mvp * vec4(-2.0f, 0.0f, 0.0f, 0.0f);  EmitVertex();
      gl_Position = gs_in[0].position + gs_in[0].mvp * vec4(2.0f, 0.0f, 0.0f, 0.0f);  EmitVertex();
      gl_Position = gs_in[0].position + gs_in[0].mvp * vec4(0.0f, 2.0f, 0.0f, 0.0f);  EmitVertex();

    EndPrimitive();
}
```

Fragement Shader

```
#version 430 core

in vec3 outColor;
out vec4 color;

void main(){

   color = vec4(outColor, 1.0f);

}
```

Geometry Model.cpp

```
GeometryModel::GeometryModel(GLuint program, Camera* camera){

this->program = program;
this->camera = camera;

GLfloat points[] = {
0.0f,  0.0f, 0.0f, 1.0f, 0.0f, 0.0f, //passing in 1 point
};

glBindVertexArray(vao);
glGenBuffers(1, &vbo);

glGenVertexArrays(1, &vao);
glBindBuffer(GL_ARRAY_BUFFER, vbo);
glBufferData(GL_ARRAY_BUFFER, sizeof(points), &points, GL_STATIC_DRAW);

glEnableVertexAttribArray(0);
glVertexAttribPointer(0, 3, GL_FLOAT, GL_FALSE, 6 * sizeof(GLfloat), 0);
glEnableVertexAttribArray(1);
glVertexAttribPointer(1, 3, GL_FLOAT, GL_FALSE, 6 * sizeof(GLfloat), (GLvoid*)(3 * sizeof(GLf

glBindVertexArray(0);
}
```

Geometry Model Render Function

```
void GeometryModel ::render() {

glUseProgram(this->program);

glm::mat4 model;
model = glm::translate(model, position);

glm::mat4 mvp = camera->getprojectionMatrix() * camera->getViewMatrix() * model;

GLint vpLoc = glGetUniformLocation(program, "mvp");
glUniformMatrix4fv(vpLoc, 1, GL_FALSE, glm::value_ptr(mvp));

glBindVertexArray(vao);
glDrawArrays(GL_POINTS, 0, 1);
glBindVertexArray(0);

}
```

Shader Loader

- Make changes to shaderLoader.h and .cpp to take in compile, attach and link vs, gs and fs.

- Add function to take all three shader in ShaderLoader.h

```
GLuint CreateProgram(char* vertexShaderFilename, char* fragmentShaderFilename, char* geometryShaderFilename);
```

Shader Loader.cpp

- Copy and paste the createProgram function that takes only the vs and fs.
- In the new createProgram function edit the function to accept gs as well.
- Then add in the following.
- std::string geometry_shader_code = ReadShader(geometryShaderFilename);
- GLuint geometry_shader = CreateShader(GL_GEOMETRY_SHADER, geometry_shader_code, "geometry shader");
- glAttachShader(program, geometry_shader);

Usage

- In the main.cpp

```
#include "GeometryModel.h“
GeometryModel *geomModel;
```

- In init function

```
GLuint geomProgram =
    shader.CreateProgram("Assets/shaders/geomModel.vs",
  "Assets/shaders/geomModel.fs",
  "Assets/shaders/geomModel.gs");

geomModel = new GeometryModel(geomProgram, camera);
geomModel->setPosition(glm::vec3(6.0f, 1.0f, 0.0f));
```

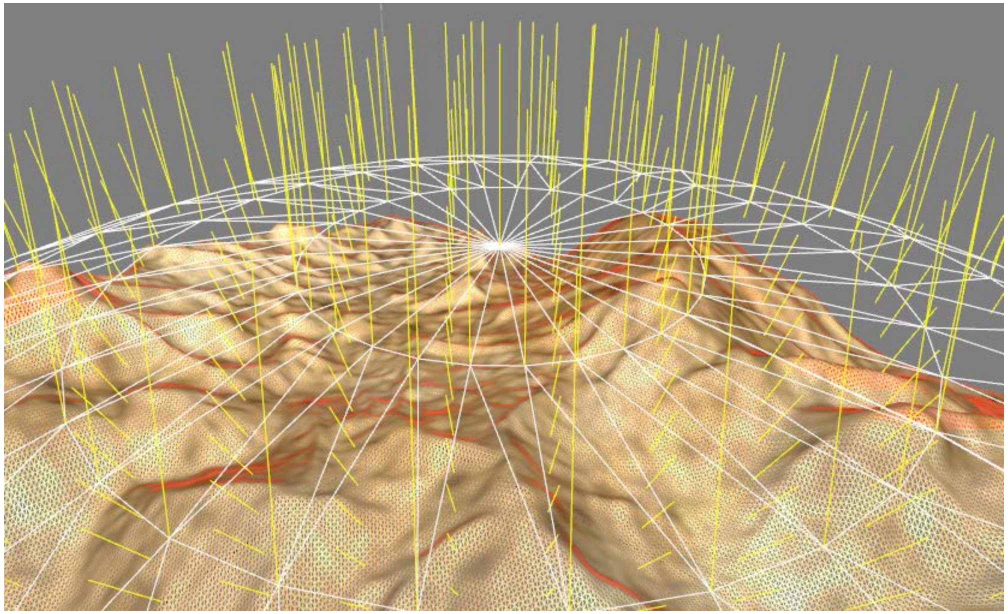
Usage

- In the render function in main.cpp render the geometry model

```
geomModel->render();
```

- The ouput should be a triangle though only a point in passed in

Applications



- Show geometry normals

Applications

- Reference
  - https://developer.nvidia.com/gpugems/GPUGems/gpugems_ch07.html

Exercises

- Implement geometry shader.
  - Take a point as an input and creat a quad out of it.
  - Create texture coordinates for each new point created.
  - Apply a grass texture on the quad created.
  - Try rotating the quad locally
  - Move or rotate the quad in the world space.