Information Visualization

W08: Exercise - Shader Programming

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- W14 5/31 Implementation of Volume Rendering
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GLSL

- Types
  - void, bool, int, float
  - vec2, vec3, vec4
  - bvec2, bvec3, bvec4
  - ivec2, ivec3, ivec4
  - mat2, mat3, mat4
  - sampler2D, sampler3D
  - …

https://www.khronos.org/files/webgl/webgl-reference-card-1_0.pdf

GLSL

- Vector Components
  - {x, y, z, w} represent points or normals
    e.g.: pos.x, pos.y, pos.z, pos.w
  - {r, g, b, a} represent colors
    e.g.: col.r, col.g, col.b, col.a
  - {s, t, p, q} represent texture coordinates
    e.g.: tex.s, tex.t, tex.p, tex.q
  - Swizzled and replicated
    e.g.: pos.xy, pos.xx, pos.zy, …

GLSL

- Matrix Components
  - Column-major
  - Constructors

    e.g.:
    ```
    mat2(float)
    mat2(vec2, vec2)
    mat2(float,float,float,float)
    ```
  - Access components of a matrix with array subscripting syntax

    e.g.)
    ```
    mat4 m;
    m[1] = vec4(2.0);
    m[0][0] = 1.0;
    ```

GLSL

- Qualifiers
  - `const` constant parameter
  - `attribute` input value of vertex shader
  - `uniform` global value
  - `varying` output value of vertex shader
    input value of fragment shader

https://www.khronos.org/files/webgl/webgl-reference-card-1_0.pdf

GLSL

- Built-In Inputs and Outputs (Vertex Shader)
  - Input

    `gl_Position` transformed vertex position

    `gl_PointSize` transformed point size

GLSL

- Built-In Inputs and Outputs (Fragment Shader)
  - Inputs

`gl_FragCoord`	fragment position (framebuffer)
`gl_FrontFacing`	fragment belongs to a front-facing primitive
`gl_PointCoord`	fragment position (point)

  - Oputputs

`gl_FragColor`	fragment color
`gl_FragData[n]`	fragment color for color attachment n

GLSL

- Built-In Functions
  - Angle and Trigonometry Functions
    - `T radians(T degrees)`
    - `T degrees(T radians)`
    - `T sin(T angle)`
    - `T cos(T angle)`
    - `T tan(T angle)`
    - …

GLSL

- Built-In Functions
  - Exponential Functions
    - `T pow(T x, T y)`
    - `T exp(T x)`
    - `T log(T x)`
    - `T sqrt(T x)`
    - …

GLSL

- Built-In Functions
  - Common Functions
    - `T abs(T x)`
    - `T floor(T x), T ceil(T x)`
    - `T min(T x, T y), T max(T x, T y)`
    - `T clamp(T x, T minVal, T maxVal)`
    - `T mix(T x, T y, T a)`
    - …

GLSL

- Built-In Functions
  - Geometric Functions
    - `T length(T x)`
    - `float distance(T p0, T p1)`
    - `float dot(T x, T y)`
    - `vec3 cross(vec3 x, vec3 y)`
    - `T normalize(T x)`
    - `T reflect(T l, T n)`
    - …

Three.js

- Built-in uniforms and attributes
  - Vertex Shader
    - `uniform mat4 modelMatrix;`
    - `uniform mat4 modelViewMatrix;`
    - `uniform mat4 projectionMatrix;`
    - `uniform mat4 viewMatrix;`
    - `uniform mat3 normalMatrix;`
    - `uniform vec3 cameraPosition;`
    - `attribute vec3 position;`
    - `attribute vec3 normal;`
    - …

http://threejs.org/docs/api/renderers/webgl/WebGLProgram.html

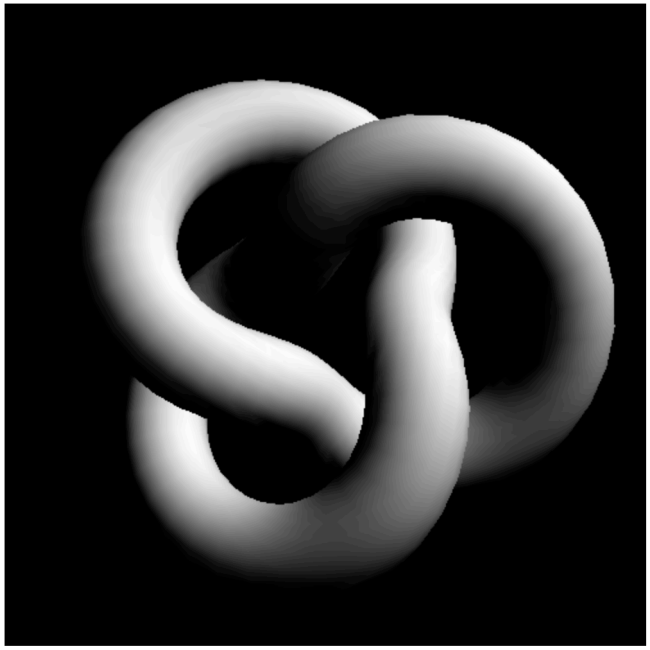
Three.js

- Built-in uniforms and attributes
  - Fragment Shader
    - `uniform mat4 viewMatrix;`
    - `uniform vec3 cameraPosition;`

http://threejs.org/docs/api/renderers/webgl/WebGLProgram.html

Torus Knot

- Download files named as main01.js and w08_ex01.html
- Open w08_ex01.html with your web browser



Torus Knot with Three.js

- THREE.TorusKnotGeometry

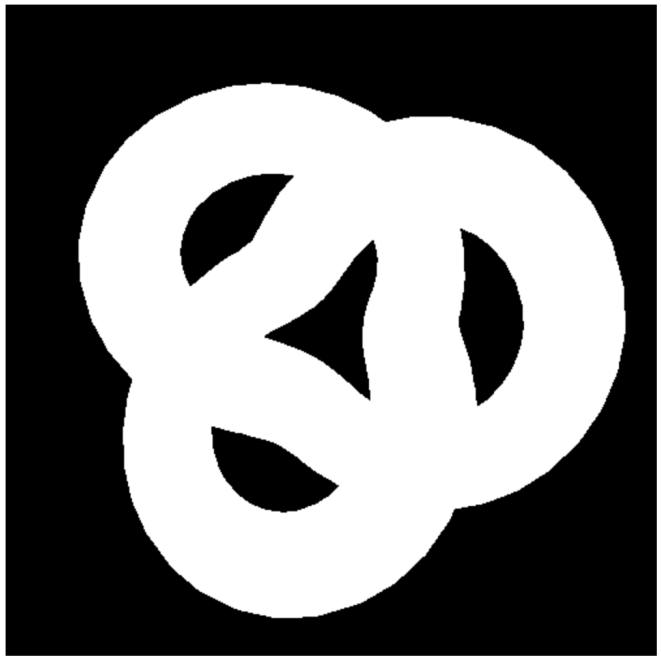
```
var geometry = new THREE.TorusKnotGeometry(1, 0.3, 100,20);
var material = new THREE.MeshLambertMaterial();

var torus_knot = new THREE.Mesh( geometry, material );
scene.add( torus_knot );
```

http://threejs.org/docs/#Reference/Extras.Geometries/TorusKnotGeometry

Torus Knot with Shaders

- Download files named as main02.js and w08_ex02.html
- Open w08_ex02.html with your web browser



Simple Shaders

- Describes shaders with <script>
  - Vertex Shader

```
<script type="x-shader/x-vertex" id="shader.vert">
void main()
{
    gl_Position = projectionMatrix * modelViewMatrix *
vec4( position, 1.0 );
}
</script>
```

Simple Shaders

- Describes shaders with <script>
  - Fragment Shader

```
<script type="x-shader/x-fragment" id="shader.frag">
void main(
{
    gl_FragColor = vec4( 1.0, 1.0, 1.0, 1.0 );
}
</script>
```

Simpler Shaders

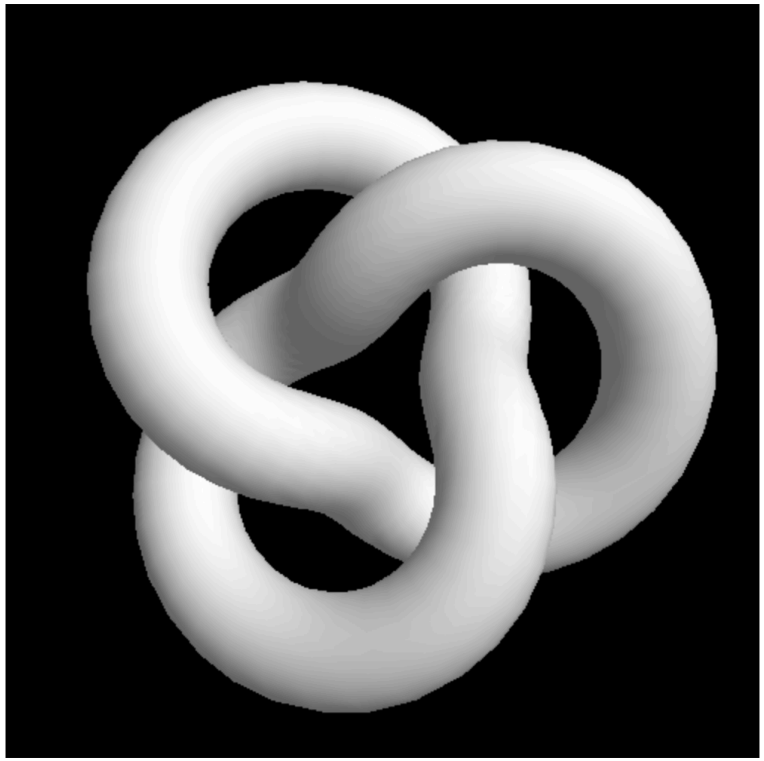
- Uses THREE.ShaderMaterial instead of THREE.MeshLambertMaterial

```
var material = new THREE.ShaderMaterial({
    vertexColors: THREE.VertexColors,
    vertexShader: document.getElementById('shader.vert').text,
    fragmentShader: document.getElementById('shader.frag').text
});
```

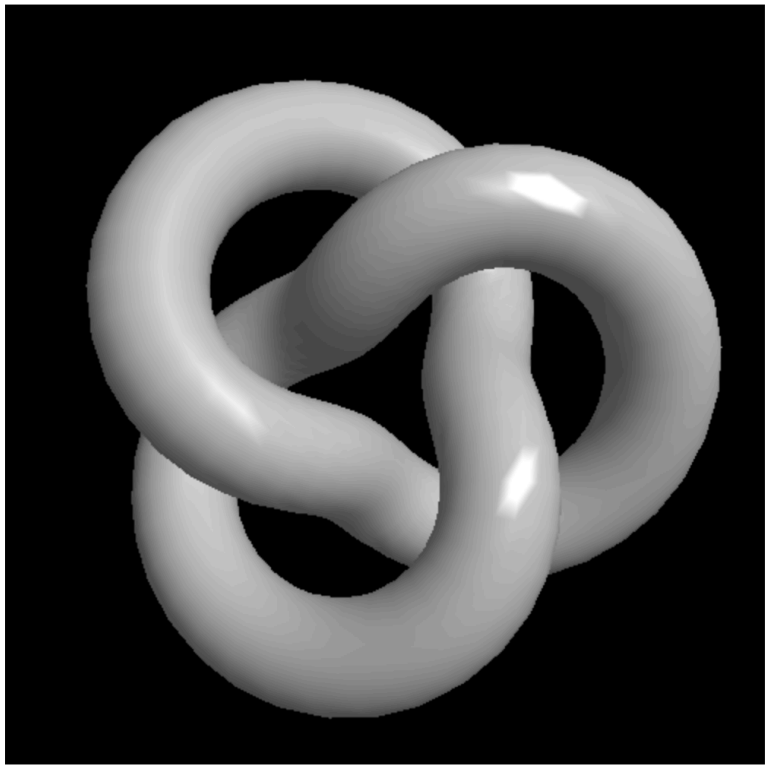
http://threejs.org/docs/#Reference/Materials/ShaderMaterial

Task 1

- Implement Gouraud shading for the rotating torus knot geometry



Lambertian reflection model



Phong reflection model

Hint

- Vertex Shader

```
<script type="x-shader/x-vertex" id="gouraud.vert">
    varying vec3 point_color;
    varying vec4 point_position;
    varying vec3 normal_vector;
    uniform vec3 light_position;

    // LambertianReflection function here

    void main()
    {
        point_position = modelViewMatrix * vec4( position, 1.0 );
        normal_vector = normalMatrix * normal;

        vec3 C = color;
        vec3 L = normalize( light_position - point_position.xyz );
        vec3 N = normalize( normal_vector );
        point_color = LambertianReflection( C, L, N );
        gl_Position = projectionMatrix * point_position;
    }
</script>
```

Hint

- Lambertian Reflection

```
vec3 LambertianReflection( vec3 C, vec3 L, vec3 N )
{
    float ka = 0.4;
    float kd = 0.6;

    float dd = max( dot( N, L ), 0.0 );
    float Ia = ka;
    float Id = kd * dd;
    return C * ( Ia + Id );
}
```

Hint

- Phong Reflection

```
vec3 PhongReflection( vec3 C, vec3 L, vec3 N )
{
    float ka = 0.3;
    float kd = 0.5;
    float ks = 0.8;
    float n = 50.0;

    vec3 R = reflect( -L, N );
    float dd = max( dot( N, L ), 0.0 );
    float ds = pow( max( dot( R, V ), 0.0 ), n );
    if ( dd <= 0.0 ) { ds = 0.0; }

    float Ia = ka;
    float Id = kd * dd;
    float Is = ks * ds;
    return C * ( Ia + Id + Is );
}
```

Hint

- Fragment Shader

```
<script type="x-shader/x-fragment" id="gouraud.frag">
     varying vec3 point_color;

     void main()
     {
          gl_FragColor = vec4( point_color, 1.0 );
     }
</script>
```

Hint

- ShaderMaterial

```
var material = new THREE.ShaderMaterial({
    vertexColors: THREE.VertexColors,
    vertexShader: document.getElementById('gouraud.vert').text,
    fragmentShader: document.getElementById('gouraud.frag').text,
    uniforms: {
        light_position: { type: 'v3', value: light.position }
    }
});
```

Uniform types:

- `i` `int` `int`
- `f` `float` `float`
- `v2` `THREE.Vector2` `vec2`
- `v3` `THREE.Vector3` `vec3`
- `v4` `THREE.Vector4` `vec4`
- `c` `THREE.Color` `vec3`
- …

https://github.com/mrdoob/three.js/wiki/Uniforms-types

Task 2

- Implement Phong shading for the rotating torus knot geometry
- Compare the rendering result with Gouraud shading

Advanced Tasks

- Implement shaders based on the following reflection models
  - Blinn-Phong reflection (Task 3)
  - Cook-Torrance reflection (Task 4)
  - Toon reflection (Task 5)

Polling

- Take the poll
  - Student ID Number
  - Name
  - URL to Task 1
  - URL to Task 2
  - URL to Task 3 (advanced)
  - URL to Task 4 (advanced)
  - URL to Task 5 (advanced)