CG1 WS 20/21 - Exercise 3: Shading

Technische Universität Berlin - Computer Graphics
Date 10. December 2020 **Deadline** 06. January 2021
Prof. Dr. Marc Alexa, Ugo Finnendahl, Max Kohlbrenner

Shading (7 points)

In order to render geometry and materials, a dedicated graphic processing unit (GPU) is usually used. It provides a rendering pipeline that does most of the calculations highly paralellized. That pipeline is mostly fixed and not programmable. The parts that are programmable are called shaders. The two main shaders are the *vertex shader* and the *fragment shader*. First the vertex shader operates vertex wise than later the fragment shader is executed per pixel. Depending on the interface used, one is restricted to a certain programming language. In our case we use *WebGL* and have to write *GLSL ES*, which has a `c` like syntax. Other interfaces would be for example DirectX, OpenGL, Vulkan and Metal, which use similar languages. In this exercise sheet you have to program different shaders. The shaders used for rendering in `Three.js` are defined object wise in the material.

As CPU and GPU do not share memory we need to pass all relevant data to the GPU. There are two different concepts for variables that we can pass: `Uniform` and `attributes`. A `uniform` variable is defined global for an object and is valid for all vertices and pixels rendered. Therefore it is accessible and constant in both the vertex and fragment shaders. An `attribute` variable is defined per vertex and is only passed to the vertex shader. For communication between the vertex and the fragment shader `varying` variables are used. They get passed from vertex to fragment shaders and the given value is interpolated between the vertex values (see exercise slides for more detail).

The tasks in detail are:

1. Setup a basic scene using `setupGeometry` in `helper.ts` and create the gui (`Settings` and `createGUI` are provided in `helper.ts`) (*0 points*).

2. **Basic Ambient Shader** We have given you a basic vertex and fragment shader which together output a constant vertex and color. Complete them to render the scene using a basic ambient shader. The vertex shader needs to calculate the normalized device coordinates like in the last exercise. The fragment shader computes the resulting pixel color using the light color and the ambient reflectance, both should be adjustable using the *Ambient color* picker and *Ambient reflectance* slider in the gui. (*1 point*)

   Restriction: You have to use `RawShaderMaterial` in this and all following tasks, **not** `ShaderMaterial`.

   Hint: `Three.js` already passes a lot of useful `uniforms` and `attributes`, those are listed and commented in the basic shader examples. The light color and reflectance needs to be passed additionally as `uniform`.

3. **Normal Shader** Implement a simple normal shader that visualizes the normal direction of the surface in world space as a color. Map the normals bijective from the unit sphere to the RGB color space. Note that the *normal* `attribute` that is predefined by `Three.js` is defined in local coordinates. (*1 point*)

   Hints: 1. When a linear transformation is applied to a surface, its normals need to be transformed correctly using the inverse transpose of the transformation, you might have to pass this matrix as an additional `uniform`.[1] 2. In the pipeline, the normals are defined per vertex and need to get (transformed and) passed to the fragment shader as an interpolated quantity using a `varying`.

4. **Toon Shader** Implement a toon shader. The color is based on discrete thresholds of the angle between the viewing direction and the surface normal. The larger the angle, the darker the surface color. You need to define four different shades of a color you like. Use pixel wise color calculation. (*0.5 points*).

[1] There are two transformed spheres in the scene. One is scaled using the local coordinate system, the other is scaled in the geometry and has therefore already corrected normals. On the screen both spheres should look the same.

5. **Diffuse Light Shader** Implement a diffuse (*Lambert*) illumination shader with a single point light source. The point light source should be movable using the gui and add a visualization in form of a sphere to the scene. Changes to the diffuse reflectance slider and color picker should lead to the correct update of pixel colors. You can use either gouraud or phong shading. Whether you add an ambient light component is your choice and does not affect the grading.

   Hint: You do not need any `Light` object provided by `Three.js`, as they only work on `Three.js Materials`. Just use a simple 3D vector representing the light. (*1 point*).

6. **Specular Light Shaders** Now implement the complete *Phong* illumination model by adding a specular component to the lambert and ambient calculations. Implement the two common interpolation methods for it: *Gouraud* and *Phong* using separate shaders. Again all changes to the according reflectance sliders and color pickers should lead to the correct update of pixel colors. The magnitude slider should control the falloff parameter m of the Phong light model. The point light source should be movable using the gui. (*3 points*)

7. **Blinn-Phong Specular Light Shader** Implement a *Blinn-Phong* shader using the Phong interpolation technique. The reflectance sliders and color pickers should update like before. The magnitude slider should now control the falloff parameter n of the Blinn-Phong light model. The point light source should be movable using the gui. (*0.5 points*)

Requirements

- Exercises must be completed individually. Plagiarism will lead to exclusion from the course.
- Submit a `.zip` file of the `src` folder of your solution through ISIS by **06. January 2021, 23:59**.
- *Naming convention*: {firstname}_{lastname}_cg1_ex{#}.zip (for example: jane_doe_cg1_ex3.zip).
- You only hand in your `src` folder, make sure your code works with the rest of the provided skeleton.