Computer Graphics - Exercise 05

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Winter Semester 2022

1 Lighting Models

a) **What are the roles of the three different parts in the Phong shading model (ambient,diffuse, specular)?**

   (a) ambient: Adds a constant brightness to the entire surface of the objects. It can be interpreted as approximating indirect light.

   (b) diffuse: This model describes the Lambertian Reflection. Thereby the reflected light depends on the normal and the angle of incidence of the light. This allows, for example, the shape of an object to be recognizable to the observer.

   (c) specular: In this model, the reflected light depends of the outgoing light direction and the normal of the reflecting surface. As the name suggests it describes how specular an object is.

b) **What is the role of the exponent in the specular component?**
The exponent in the specular component is also known as "shininess" or the "shining parameter". It influences the distribution of the reflected light. The larger n, the narrower the distribution of the outgoing light intensity relative to the outgoing light angle. The higher n, the "shinier" an objects appears.

c) **Why do we sometimes use multiple normals per vertex, while sometimes we only use one? How are vertex normals computed from face normals and why is subsequent normalization of the result necessary?**
To represent smooth surfaces, only one normal per vertex is used. This allows the normal to be interpolated for each position on the adjacent polygons. This way the shading creates the illusion of smooth surfaces. To represent (sharp) edges on the other hand, the adjacent vertices must have multiple normals. To compute the vertex normales, one sums up the normals of the adjacent polygons. Optionaly one scales the normals by the polygon area or by its angle adjacent to the vertex. Then the result is normalized. Subsequent normalization is always needed, because the interpolation of the normals of length 1 does not necessarily result in a normal of length 1.

d) **How can Phong shaded surfaces appear smooth, but their silhouettes appear sharp?**
Objects consist of polygons. For shading surfaces, one does not normally use the normals of the polygons, but one interpolates the normals using the vertex normals. therefore the illumination appears smooth, while the object silhouette stays sharp.

2 Ray Tracing Fundamentals

a) **Explain the different kinds of rays: primary ray, secondary ray, shadow ray, reflection ray, and transmission ray.**

- **Primary rays**: are the rays produces by the camera/view
- **Secondary rays**: is the set of all other rays (shadow rays, reflection rays, transmission rays)
- **Shadow rays**: create shadow by shooting secondary rays from the point of intersection to all light sources. If a shadow ray intersect another object on the way from the surface to the light source, the surface will have shadow on it (no light contribution from that light except ambient)
- **Reflection rays**: Used to achieve mirroring of the scene on reflective surfaces. View ray (primary ray) is reflected at surface → reflected ray $\mathbf{R}$. This ray is treated (almost) identically to view ray. New intersections can be evaluated recursively for multiple reflections. Color of reflection ray is added to color at starting point.
- **Transmission ray**: are rays transmitted through opaque media. For an incidence ray $\mathbf{I}$ the transmitted vector $\mathbf{T}$ can be calculated from Snell's law by

$$\mathbf{T} = -\frac{\eta_i}{\eta_t}\mathbf{I} + \left(\frac{\eta_i}{\eta_t}\cos\theta_i - \sqrt{1 - \left(\frac{\eta_i}{\eta_t}\right)^2 (1 - \cos^2\theta_i)}\right)\mathbf{N}$$

  where η_i, η_t are the indices of refraction in the incidence and the transmission medium respectively and θ_i the angle of incidence from the normal of the surface.

b) **Why is global illumination a recursive problem? How can a stopping criterion be derived from reflection/transmission coefficients?**

- Global illumination is a recursive problem because light rays can get reflected and transmitted in the worst case infinitely many times back an forth between two reflecting or transmitting surfaces. The interaction has to be modeled by recursively shooting secondary rays from new intersection points.
- A stopping criterion can be derived from the reflection/transmission coefficients by tracing the recursion until the contribution to the color is negligible, i.e. trace until

$$\prod_i k_{r,i} < \epsilon_r$$

3 Ray Tracing II

See code