TP3 - Rendering

NPM3D - M2 MVA

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1 Image Loading and display

Given a four-channel image I, we convert it to a point cloud with normal. The first three channels which represent the normal vector for each point are extracted and the fourth channel is discarded. The image is supposed to lie in the xy-plane, i.e. $z = 0$. Thus the coordinate of a point at pixel (x, y) is simply $(x, y, 0)$. The normal is normalized and scaled to $[-1, 1]$ in order to ensure the following calculations.

2 Diffuse Shading

Given a point cloud $\mathcal{X} = \{x^1, \dots, x^M\}$ with normals $\mathcal{N} = \{n^1, \dots, n^M\}$, a light source l located at (l_x, l_y, l_z) and a camera position c located at (c_x, c_y, c_z), we intend to render the image by using different method. The basic rendering equation is as following:

$$L_o(\omega_o) = L_i(\omega_i) f(\omega_i, \omega_o)(n \cdot \omega_i)$$

where for $\forall m \in M$, we have

$$\begin{aligned} \omega_i^m &= x^m - (l_x, l_y, l_z) \\ \omega_o^m &= x^m - (c_x, c_y, c_z) \\ f(\omega_i, \omega_o) &= f^s(\omega_i, \omega_o) + f^d(\omega_i, \omega_o) \end{aligned}$$

In this section the diffuse color reponse is calculated by Lambert BRDF and the specular color response is set to 0. Given a diffuse coefficient $k^d = 1$, an albedo color $c^d = (0.6, 0.75, 0.5)$, f^d is calculated as:

$$f^d(\omega_i^m, \omega_o^m) = \frac{k^d \cdot c^d}{\pi}$$

which is independent from the point cloud. The rendering result is shown in figure 1.

Figure 1: Lambert BRDF

3 Specular Materials

(a) We assume that the camera is set at $(50, 10, 1)$. In order to enrich the shading function, we add a specular color response by using Blinn-Phong BRDF. First of all we calculate the halfvector w_h as:

$$w_h^m = \frac{\omega_i^m + \omega_o^m}{\|\omega_i^m + \omega_o^m\|}$$

Then we have:

$$f^s(\omega_i^m, \omega_o^m) = k^S (n \cdot \omega_h^m)^S$$

where $k^S = 0.1$ is the specular coefficient and $S = 0.5$ is the shininess coefficient. Then the final color response is the sum of the specular one and the diffuse one. The rendering result is shown in figure 2.

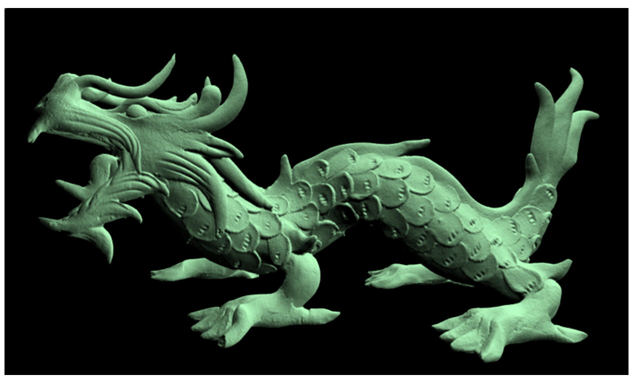

Figure 2: Blinn-Phong BRDF with $k^S = 0.1$

Compared to the previous result, we find that the tail of the dragon is darker, since we take into consideration the camera position. What's more, the shadow is more realistic.

k^S controls the ratio between the specular color response and the diffuse one. When it is larger, the final color will change (like in figure 3).

Figure 3: Blinn-Phong BRDF with $k^S = 0.5$

(b) In this part, we replace the Blinn-Phong BRDF by a physically-based microfacet model taking the general form of the Cook-Torrance BRDF. The following formulas are implemented:

$$
\begin{aligned}
f^s(\omega_i, \omega_o) &= \frac{D(\omega_i, \omega_o)F(\omega_i, \omega_h)G(\omega_i, \omega_o)}{4(n \cdot \omega_i)(n \cdot \omega_o)} \\
D(\omega_i, \omega_o) &= \frac{\alpha^2}{\pi\Big(1 + (\alpha^2 - 1) \cdot (n \cdot \omega_h)^2\Big)^2} \\
F(\omega_i, \omega_o) &= F_0 + (1 - F_0)(1 - \omega_i \cdot \omega_h)^5 \\
G_1(\omega) &= \frac{(n \cdot \omega)}{(n \cdot \omega)(1 - k) + k} \\
G(\omega_i, \omega_o) &= G_1(\omega_i)G_2(\omega_o)
\end{aligned}
$$

with $k = \alpha\sqrt{\frac{2}{\pi}}$. Note that $F_0 = \left(\frac{n-1}{n+1}\right)^2$ when $\beta = 0$ and a specific albedo color vector otherwise.

In the experiment, we take $\alpha = 0.5$, $\beta = 0$, $n = 0.5$. The result is shown in figure 4.

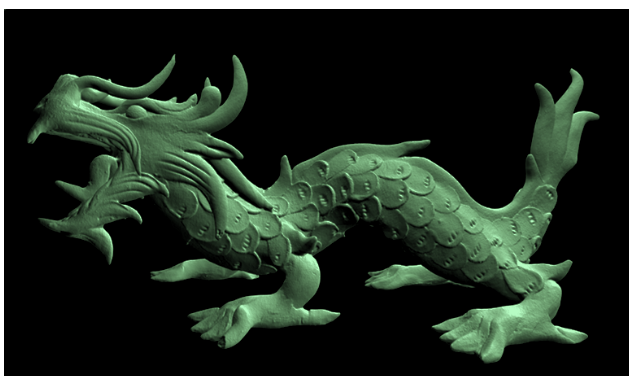

Figure 4: Cook-Torrance BRDF

4 Remark

The following normalizations are performed in order to get a good rendering.

- All the dot product between two vectors are clipped between 0 and 1
- L_o is normalized between 0 and 1.