Improved Diffuse Anisotropic Shading

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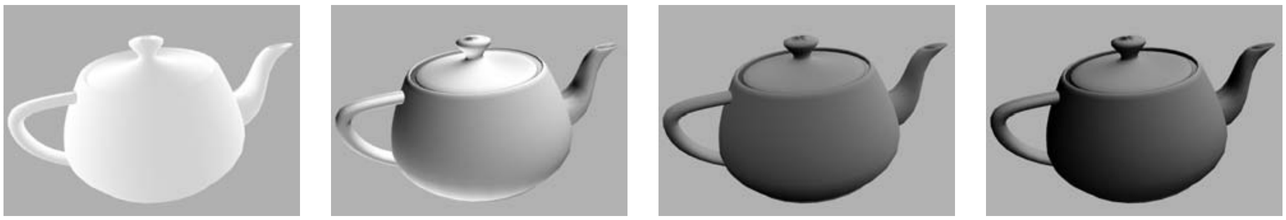

Maximum normal   Proposed method

Figure 1: Comparison between diffuse light calculated with maximum normal and proposed method for two directions of anisotropy.

Abstract

Cloth, hair, brushed metal, and other surfaces with small, regular surface features exhibit anisotropic reflectance properties for which common isotropic shading methods are not suited. Shading of such materials is often implemented by computing the normal giving the maximum light contribution instead of solving the integral that is the sum of all reflected light. In this paper we show that this integral can be simplified if the direction to the viewer and fibre geometry is not taken into account. Still, this will give a more accurate result than the very rough simplification of using the maximum contribution. This computation is simple for diffuse light. However, the specular light still needs some more elaboration to work.

Keywords: anisotropic shading, diffuse light

1 Introduction

Anisotropic shading is a shading technique that could be used for materials like hair and fabrics like silk [Banks 1994]. Such materials have very small fibres with a main direction.

Poulin and Fournier [Poulin 1990] proposed a model for such materials that is rather complex and have so far been too expensive to implement for real-time applications. Even with the processing power available in graphics hardware today, a simpler model is still required.

One such simplified and frequently used model proposes that the light reflected by fibres is computed using the normal vector that results in the largest contribution of reflected light [Heidrich 1998]. This normal is obtained by projecting the light vector along the tangent onto the normal plane, which is the plane spanned by the surface normal and binormal. For the diffuse light the maximum normal is computed as

$$\mathbf{n_{max}} = \frac{\mathbf{l} - \mathbf{t}(\mathbf{l} \cdot \mathbf{t})}{\| \mathbf{l} - \mathbf{t}(\mathbf{l} \cdot \mathbf{t}) \|}. \quad (1)$$

Poulin and Fournier compute the total light reflected from the fibre. Moreover they take geometry and viewer position into account. The total light can be computed by summing the dot products using an integral, and this integral is modified by a factor depending on the viewer position. None of these considerations are taken into account in the simple model.

2 Proposed Method

We propose a trade-off which will sum the light while not taking geometry and viewer position into account. The surface normal and binormal can be used as an orthogonal base for computing any unit normal in the normal plane. This can be expressed as

$$\mathbf{n}' = \mathbf{n} \cos\theta + \mathbf{b} \sin\theta. \quad (2)$$

However, the resulting integral will be simpler by using $\mathbf{n_{max}}$ and $\mathbf{n_{min}}$ as a base. Figure 2 illustrates these vectors.

The normal contributing least to the light is the one where $\mathbf{n_{min}} \cdot \mathbf{l} = \mathbf{0}$, it is obtained by

$$\mathbf{n_{min}} = \frac{\mathbf{l} \times \mathbf{n_{max}}}{\| \mathbf{l} \times \mathbf{n_{max}} \|}. \quad (3)$$

The minimum of a cosine function is offset by $\pi/2$ from the maximum. This is excatly the case for $\mathbf{n_{min}}$ and $\mathbf{n_{max}}$, hence these can be used as a base. The light is computed by

$$\Phi = \frac{1}{\pi} \int_0^{\rho} I_{\min} \cos\theta + I_{\max} \sin\theta \, d\theta, \quad (4)$$

$$\rho = \cos^{-1}(\mathbf{n_{min}} \cdot \mathbf{b}). \quad (5)$$

Light is integrated over the portion of the fibre that would be visible if occlusion occured from the surface plane and not from other

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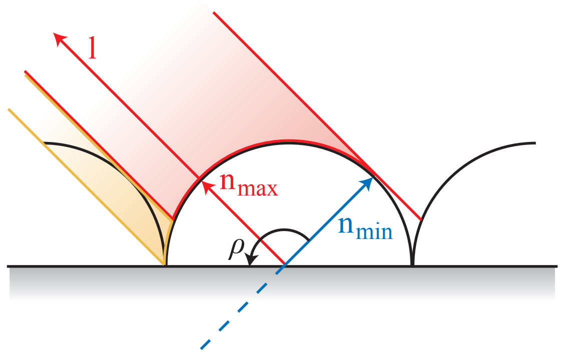

Figure 2: Lit area and integration base vectors.

fibres, and then divided by π as if no occlusion occured. Figure 2 illustrates the integration, the red area is actually lit but the red and yellow areas are integrated.

The integral in (4) is very similar to what Poulin and Fournier propose, however

$$I_{\text{min}} = \mathbf{n_{min}} \cdot \mathbf{l} = 0 \tag{6}$$
$$I_{\text{max}} = \mathbf{n_{max}} \cdot \mathbf{l}. \tag{7}$$

The equation can therefore be reduced to

$$\Phi = \frac{1}{\pi} \int_0^\rho I_{\text{max}} \sin\theta \, d\theta, \tag{8}$$

evaluation of which leads us to

$$\Phi = \frac{1}{\pi} \left(-I_{\text{max}} \cos\rho + I_{\text{max}} \cos 0 \right). \tag{9}$$

However, from (5) we have $\rho = \cos^{-1}(\mathbf{n_{min}} \cdot \mathbf{b})$, so the final formulation is

$$\Phi = \frac{1}{\pi} (\mathbf{l} \cdot \mathbf{n_{max}})(1 - \mathbf{n_{min}} \cdot \mathbf{b}). \tag{10}$$

In this form all trigonometric functions are eliminated, leaving only normalization, dot- and cross product, all of which are efficient operations in fragment shaders on current hardware.

3 Discussion

The proposed method is a compromise between accuracy and speed—far more accurate than and the simplistic maximum normal method but faster and less accurate than the Poulin method.

Which method is most suitable naturally depends on the situation, but we have presented a reasonable compromise in cases where performance is required and the maximum normal method is not enough.

Figure 1 compares our method with maximum normal lighting. Keep in mind that only diffuse light is used.

Research continues in search of a comparable method for the specular component and a more accurate complete solution.

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