An Interactive Shader for Natural Diffraction Gratings

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Abstract

In nature, color production is the result of physical interaction of light with a surface's nanostructure. In his pioneering work, Stam developed limited reflection models based on wave optics, capturing the effect of diffraction on very regular surface structures. We propose an adaption of his BRDF model that can handle complex natural gratings. On top of this, we describe a technique for interactively rendering diffraction effects, as a result of physical interaction of light with biological nano-structures such as snake skin. As input data, our method uses discrete height fields of natural gratings acquired by using atomic force microscopy (AFM). Based on Taylor Series approximation, we leverages precomputation to achieve interactive rendering performance (about 5-15 fps). We demonstrate results of our approach using surface nano-structures of different snake species applied on a measured snake geometry. Lastly, we evaluate the quality of our method by a comparison of the maxima for peak viewing angles using the data produced by our method against the maxima of the grating equation.

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Chapter 1

Results

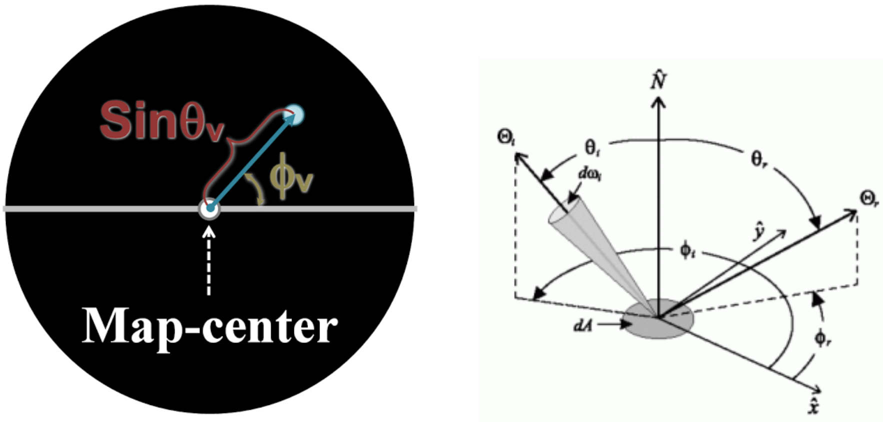
In this chapter we examine the rendered output results of our implementation of our BRDF models applied to different input patches such as Blaze grating or Elaphe ?? and Xenopeltis ?? snake nano-scaled surface sheds. We are discussing and comparing both, their BRDF maps 1.1 and the corresponding renderings on a snake geometry like shown in section ?? for various input parameters. Last we also show a real experimental image showing the effect of diffraction for similar parameters like we have.

1.1 BRDF maps

A BRDF map shows a shader's output for all possible viewing directions for a given, fixed, incident light direction. We assume that each viewing direction is expressed in spherical coordinates (See appendix ??) (θ_v, ϕ_v) and is represented in the map at point

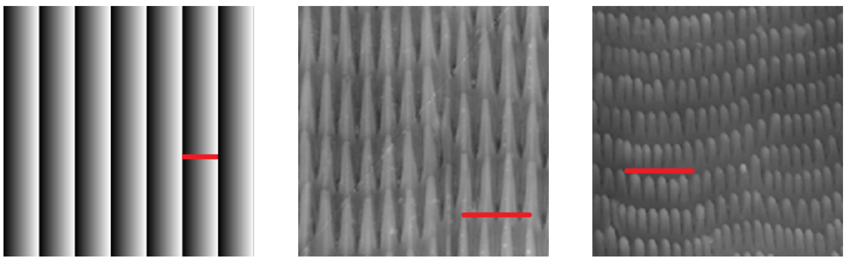
$$(x, y) = (sin(\theta_v)cos(\phi_v), sin(\theta_v)sin(\phi_v)) \tag{1.1}$$

with its origin at the map center. The light direction for normal incidence (θ_i, ϕ_i) has been fixed to $(0, 0)$ for our rendered results.



(a) BRDF map schema (b) Light reflection geometrical setup

Figure 1.1: BRDF maps[1] for different patches: $\Theta = (\theta_i, \phi_i)$ is the direction of light propagation



(a) Blaze grating with scale of 2.500 μm (b) Elaphe patch with scale of 3.270 μm (c) Xenopeltis patch with scale of 3.210 μm

Figure 1.2: Cutouts of our nano-scaled surface gratings used for rendering within our shader with a scale indicator (red line) for each patch. Note that for rendering, we use larger patches.

[1] image source of figure:

- 1.1(a): Taken from D.S.Dhillon's Paper [D.S14]
- 1.1(b): Taken from `http://math.nist.gov/~FHunt/appearance/brdf.html`

(a) Blazed grating (b) Elaphe grating (c) Xenopeltis grating

Figure 1.3: BRDF maps for different patches

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