Rendering Methods for Models with Complicated Micro Structures

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1 Overview

The male *Morpho* Butterflies have peculiar vivid cobalt blue wings caused by microscopic structures on its scales. Its color is due to structural specificity and not caused by its pigments. Those reflectional color effects are known as "structural colors".

The methodology for representing structural colors has been extensively studied from the viewpoint of anisotropic reflection, but those studies are based on phenomenological modeling of reflectance functions and specific microstructures of the target surface are disregarded.

In this paper, a physically sound structural model is proposed and a new rendering method is developed taking account of the effect of interference, diffraction, light scattering, and anisotropy and semi-periodicity of microstructure on its surface.

2 Exposition

The surface of the *Morpho Rhetenor* wing is occupied by the scales with complicated microstructure. The scale is composed of periodic vertical ridges, separated by 700-800nm. Each ridge has 8-10 shelf-like cuticle layers. The columnar arrangement of ridges (Figure 1) results strong anisotropy in iridescence property in scales.

From the structure as described above, iridescence property is treated in 2-ways. Firstly (Model A in Figure 1), the scale is treated as repeated tree-like structures. Secondly (Model B in Figure 1), the scale is treated as multilayer thin film.

I developed a method combining these two structural models and calculated iridescence function from arbitrary direction.

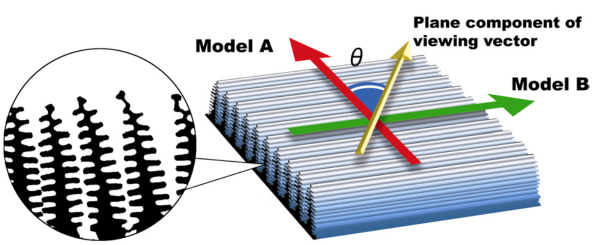

Figure 1: Combining two models to achieve anisotropy of scale

2.1 Model A: the separate lamellae model

The cross-section of the scale with a plane perpendicular to the green (Model B) vector is composed of periodical tree-like structures (as seen in left inset of Figure 1).

Kinoshita et al. [2002] proposed a analytic model of iridescence function with following assumptions, 1) the lamellae (branch) has finite length and separated by air with each adjacent lamellar (of different trees), 2) each tree is elevated randomly in vertical direction and the amount of elevation is not correlated. See Kinoshita et al. [2002] for exact solution of this model.

2.2 Model B: inclined and curved multilayer model

The cross-section of the scale with a plane perpendicular to the red (Model A) vector is considered as multilayer thin films with two alternate layers: cuticle and air. Layers are slightly inclined upward from the inside to the outside of wing. And also, slightly curved irregularly. The irradiance function of multilayer thin films is solved analytically and represented as recurrence formula as shown in Ishiguro et. al. [1985].

To calculate irradiance function I from arbitrary viewing angles θ, the irradiance function of these two models (I_A, I_B) are blended by the equation $I = \{I_A + I_B + (I_A - I_B)\cos 2\theta\}/2$. The irradiance function is converted to the RGB color intensity using CIE1931 color-matching function.

3 Results and Discussion

Figure 2 shows rendered images (left column) and the real photographs (right column). The rendered images matches well with real images qualitatively, especially in two points, 1) angular dependence of the reflectivity and 2) anisotropy of the scale reflection. For the former point, the light of 480nm wavelength reflects with the strongest intense and the wing show cyan color, which roughly corresponds to the real iridescent characteristics of *Morpho* wings.

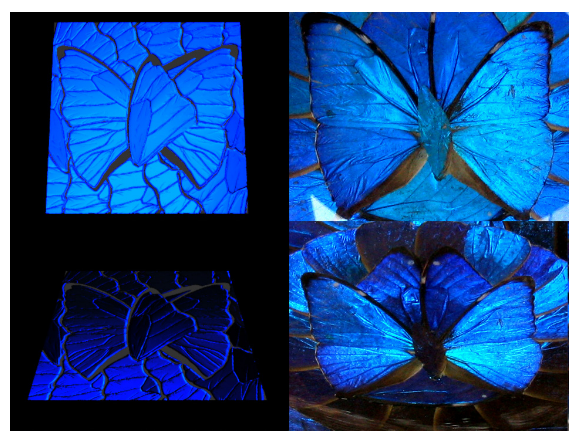

Figure 2: Rendered images (Left) and the real images (Right) of the wings of *Morpho* butterfly. Conditions: vertical sunlight, viewing angle 10 (above) and 50 (below) degrees.

References

[1] Kinoshita, S., Yoshioka, S., Fujii, Y., and Okamoto, N. 2002. Photophysics of Structural Color in the Morpho Butterflies. *Forma*, Vol.17, 103-121.

[2] Ishiguro, K., Ikeda, H., Yokota, E., 1985. 2: Nature of Multilayer Film. *Optical Thin Film*. Optical Technique Series Vol.11,Fujiwara, S., Kyoritsu Shuppan co., ltd., 25-30. (in Japanese)

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