CS348B Project Writeup

Pearlescence and Translucence in Betta fish

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Figure 1: Final Render

Project Overview

We were inspired by how iridescence and pearlescence manifests in biology. As we researched animals with such properties, we were struck by this picture of a betta fish. In particular, the betta demonstrates pearlescence in the reflection of its scales and tail, as well as translucence in its tail, making for a striking image.

Figure 2: Pearlescent Betta Fish inspiration image

Implementing translucence

The tail and fins of the fish are a great example of translucence in nature, consisting of a translucent membrane moved by short bony spines near the peduncle. There are also many folds and ridges in the fish tail, and it can be observed that these ridges allow less light to pass through, and reflect more light.

Figure 3: Opacity Maps and Results

We found a rigged model of a betta fish by Bluemesh on sketchfab which served as a great starting point, packaged with a albedo map, normal map, opacity map, roughness map, and ambient occlusion map.

In order to implement the translucence of the tail, we studied the opacity map for the rigged model and noted that black or transparent pixels corresponded to an alpha value of 0, while white pixels corresponded to an alpha value of 1. Noting that the membrane was translucent but the ridges were not, we used photoshop to greyscale and invert portions of the uv albedo map mapped to the tail and fins, and replaced the original portions of the opacity map with these portions showing a gradient of opacity. We augmented the substrate material in pbrt to take in an image as an opacity map, yielding promising results.

As we studied the model, we also noticed some artifacts in the uv mapping, causing some floating pieces. To fix this, we used the texture paint functionality in blender to correct the opacity map. The opacity is used to determine the color contribution of every other component in the material, so this fixes the artifacts without having to touch the other maps. To showcase the translucency, we added grass in the area behind the fins and tail, using a Zebra grass model by kkviz on cgtrader.

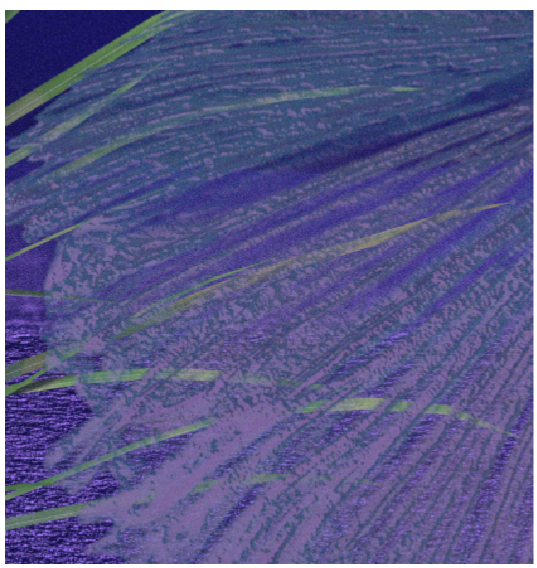

Figure 4: Translucency

Implementing Pearlescence

To mimic the lustrous metallic-like sheen of the betta fish scales, we implemented a custom shader for a pearlescence BSDF in GLSL using Blender script nodes. The mathematical model for the shader simulates multiple thin film interference, a natural phenomena where light waves reflected by upper and lower boundaries of the thin films interfere with each other, either enhancing or reducing the reflected light through constructive and destructive interference.

The pearlescent shader also takes into account polarization of the light waves, which prevents unwanted glare from light scattering and back reflections in our fish model. By differentiating between light polarized parallel and perpendicular to the plane of incidence with s-polarized and p-polarized light, respectively, we obtain a more physically accurate model, as various polarizations of light absorb differently based on the material properties of our thin film layers.

Input values for the shader include the index of refraction and the extinction coefficient for the top, middle, and substrate layers, as well as the film thickness in micrometers for the top and middle layers. Currently, an aluminum material node group serves as the input for the substrate, while iron oxide feeds input values to the top layer, and the shader output value represents the percentage of light per RGB color value an angle between the normal and the ray of light.

The equations in Figure 5 were very helpful for writing the pearlescent BSDF shader, as they allowed us to compute the complex reflection and transmission amplitudes for light of a certain angle angle and wavelength to simulate the interference behavior between different layers. By working through the equations for light interference described in Chapters 2 and 10 The Principles of Nano-Optics by Lukas Novotny and Bert Hecht, we were able to derive the overall reflected light intensity to simulate a soft and rosy pearlescent effect for our Betta specimen, as seen in Figure 8.

Looking forward, we thought it would be super interesting to try implementing a more complex BSDF model in PBRT based on the article called "A General Framework for Rendering Pearlescent Materials." The model incorporates the unique platelet micro-structures within the organic nacre material and introduces a larger parameter space for modeling more subtle nuanced behavior.

Division of Labor

$$
\begin{aligned}
r^{(\mathrm{p,s})} &= \frac{r_{1,2}^{(\mathrm{p,s})} + r_{2,3}^{(\mathrm{p,s})}\ \exp(2\mathrm{i}k_{2z}d)}{1 + r_{1,2}^{(\mathrm{p,s})} r_{2,3}^{(\mathrm{p,s})}\ \exp(2\mathrm{i}k_{2z}d)}, \\
t^{(\mathrm{p,s})} &= \frac{t_{1,2}^{(\mathrm{p,s})} t_{2,3}^{(\mathrm{p,s})}\ \exp(\mathrm{i}k_{2z}d)}{1 + r_{1,2}^{(\mathrm{p,s})} r_{2,3}^{(\mathrm{p,s})}\ \exp(2\mathrm{i}k_{2z}d)},
\end{aligned}
$$

Figure 5: Fresnel Reflection and Transmission Coefficients

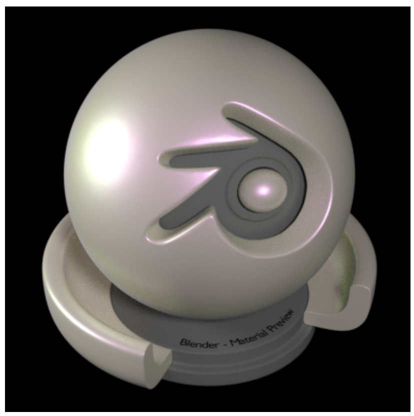

Figure 6: Initial Rendered Pearlescence Model

Figure 7: Before Pearlescence Added

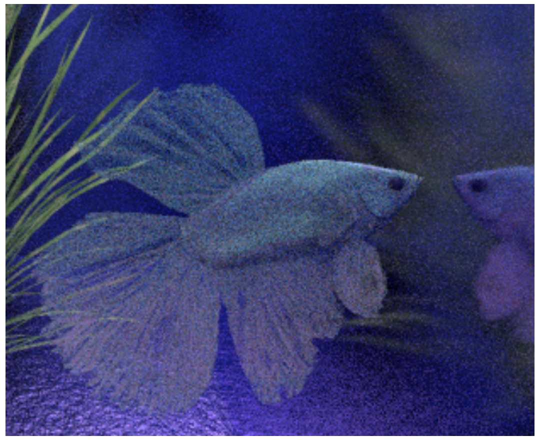

Figure 8: After Pearlescence + Subscattering Added

Vivian augmented the substrate material in pbrt, worked with photoshop and UV maps to adjust the image textures and recolor the images, researched values for subsurface scattering and specular reflection in the Stanford BSSRDF paper, and implemented translucency with opacity maps.

Kayla researched pearlescence and multi-film interference models, wrote a script in GLSL to create a new material for pearlescence, and experimented with creating a new material for a platelet-based pearlescence using the Fourier and substrate material files provided in PBRT.

We worked together to combine our materials and compose the scene, including light brightness and placement, grass placement, glass material, and roughness of the floor.

References

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